UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
PREVENTION, PESTICIDES
AND TOXIC SUBSTANCES

Note to Reader

Background: As part of its effort to involve the public in the implementation of the Food Quality Protection Act of 1996 (FQPA), which is designed to ensure that the United States continues to have the safest and most abundant food supply. EPA is undertaking an effort to open public dockets on the organophosphate pesticides. These dockets will make available to all interested parties documents that were developed as part of the U.S. Environmental Protection Agency's process for making reregistration eligibility decisions and tolerance reassessments consistent with FQPA. The dockets include preliminary health assessments and, where available, ecological risk assessments conducted by EPA, rebuttals or corrections to the risk assessments submitted by chemical registrants, and the Agency's response to the registrants' submissions.

The analyses contained in this docket are preliminary in nature and represent the information available to EPA at the time they were prepared. Additional information may have been submitted to EPA which has not yet been incorporated into these analyses, and registrants or others may be developing relevant information. It's common and appropriate that new information and analyses will be used to revise and refine the evaluations contained in these dockets to make them more comprehensive and realistic. The Agency cautions against premature conclusions based on these preliminary assessments and against any use of information contained in these documents out of their full context. Throughout this process, If unacceptable risks are identified, EPA will act to reduce or eliminate the risks.

There is a 60 day comment period in which the public and all interested parties are invited to submit comments on the information in this docket. Comments should directly relate to this organophosphate and to the information and issues available in the information docket. Once the comment period closes, EPA will review all comments and revise the risk assessments, as necessary.

These preliminary risk assessments represent an early stage in the process by which EPA is evaluating the regulatory requirements applicable to existing pesticides. Through this opportunity for notice and comment, the Agency hopes to advance the openness and scientific soundness underpinning its decisions. This process is designed to assure that America continues to enjoy the safest and most abundant food supply. Through implementation of EPA's tolerance reassessment program under the Food Quality Protection Act, the food supply will become even safer. Leading health experts recommend that all people eat a wide variety of foods, including at least five servings of fruits and vegetables a day.

Note: This sheet is provided to help the reader understand how refined and developed the pesticide file is as of the date prepared, what if any changes have occurred recently, and what new information, if any, is expected to be included in the analysis before decisions are made. **It is not meant to be a summary of all current information regarding the chemical.** Rather, the sheet provides some context to better understand the substantive material in the docket (RED chapters, registrant rebuttals, Agency responses to rebuttals, etc.) for this pesticide.

Further, in some cases, differences may be noted between the RED chapters and the Agency's comprehensive reports on the hazard identification information and safety factors for all organophosphates. In these cases, information in the comprehensive reports is the most current and will, barring the submission of more data that the Agency finds useful, be used in the risk assessments.

Jack E. Housenger, Acting Director
Special Review and Reregistration Division

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3. Ecological Effects Hazard Assessment

Mode of Action Summary

Several reviews of malathion and organophosphate toxicology exist including Matsumura (1985).

Malathion's mode of action is through acetylcholinesterase (AChE) inhibition which disrupts nervous system function. AChE is a enzyme made of protein which cleaves the neurotransmitter acetylcholine nervous system junctions. Inhibiting this enzyme leads to accumulation of the neurotransmitter thus causing signals in the nervous system to persist longer than normal. Typical symptoms for pesticides which act in this manner are defecation, urination, lacrimation, muscular twitching and weakness, and halted respiration. Malathion, along with other phosphorodithioate insecticides (those containing two sulfur atoms bonded to phosphorus) must be oxidized before they have inhibitory potency and toxicity. Oxidation occurs via cytochrome p450 and results in the conversion of the P=S group in malathion to P=O forming its oxon, malaoxon (Murphy et al., 1968). This alteration of the phosphate group enables the molecule to covalently bind AChE resulting in long lasting inhibition of the enzyme.

Malaoxon binds to AChE by mimicking the structure of enzyme's natural substrate, acetylcholine. The similarity between the size, shape, and properties of malaoxon and the neurotransmitter allow it to "fit" in the acetylcholine binding site on the enzyme.   Altering the structure of malaoxon or malathion reduces the ability of the oxon to bind AChE resulting in detoxification of the molecule. Detoxificatio reactions may be a result of enzyme or chemical action on the molecule. Detoxification occurs very rapidly in mammals giving pure malathion a very low acute toxicity [LD50 in rats is 12,500 mg/kg (Fukuto 1983)]. Common detoxification reactions for malathion (and malaoxon) are ester hydrolysis, demethylation, and phosphorothiolate ester hydrolysis. When one or more of these detoxification step are blocked by another chemical the toxicity of malathion is increased and the added chemical is considered to synergize malathion toxicity. Chemicals which increase the rate of malathion's conversi to malaoxon may also be synergists.

Important detoxification steps occur through nonspecific esterase enzymes which are capable of cleaving malathion to less toxic degradates. Biological and environmental degradates of malathion wit greatly lowered toxicity include malathion α, β, and diacids, and O-desmethyl malathion (Matsumura 1985). Since organophosphate insecticides are inhibitors of esterases (most specifically AChE) they possess the ability to block detoxification enzymes. Several organophosphate impurities present in technical malathion are known to synergize malathion toxicity probably through blocking malathion detoxification. The toxicity of several malathion impurities alone is also very high (*eg* the LD50 of O,O,S-trimethyl phosphorothioate in rats is 15 mg/kg, or 833 times more toxic than pure malathion) and cause delayed toxicity suggesting a mode of action other than AChE inhibition. Impurities can be produced through improper storage of malathion as evidenced by a 35% increase in the acute toxicity of technical malathion stored at 40^{o}C for 6 months (Fukuto 1983).

Toxicity to Terrestrial Animals

1. Birds, Acute and Subacute

An acute avian oral toxicity study using the technical grade of the active ingredient (TGAI) is required t establish the toxicity of pesticides to birds. The preferred test species is either mallard duck (a waterfowl) or bobwhite quail (an upland gamebird). Results of avian oral acute tests with Malathion are tabulated below.

Table 15. Avian Acute Oral Toxicity

Species	% a i	LD50(mg/Kg) (CL's)	Toxicity Category	MRID	Author	Classi-fication[1]
Mallard duck	95	14D LD_{50}=1485 (1020-2150)	Slightly toxic	00160000	Hudson, R.H. and Tucker, 1984, USFWS	Core
Ring-necked pheasant	95	14D LD_{50}=167 (120-231)	Moderate	00160000	Hudson R.H. and Tucker, 1984, USFWS	Supple-mental
Horned lark	95	14D LD_{50}=403 (247-658)	Moderate	00160000	Hudson, R.H. and Tucker, 1984, USFWS	Supple-mental
Sharp tailed grouse	tech	LD50 =220 (171-240)	Moderate	Reference	Crabtree, D.G., 1965, Denver Wildlife Res. Center, USFWS	Supple-mental

1 Core (study satisfies guideline). Supplemental (study is scientifically sound, but does not satisfy guideline)

Based on the data reviewed to date malathion displays low to moderate acute oral toxicity to the 3 species of birds tested by USFWS laboratories. Another referenced study was mentioned in the 1966 McEwen and Brown field study with Sharp tailed grouse (see field study section of this document). The study was conducted at the USFWS Denver Wildlife Research Center and is considered valid supplemental data. McEwen and Brown observed a similar LD50 with wild caught grouse. The most sensitive species tested was the ring-necked pheasant. The acute oral data does fulfill 71-1 testing guidelines.

Two subacute dietary studies using the TGAI are required to establish the toxicity of a pesticide to birds. The preferred test species are mallard duck and bobwhite quail. Results of subacute dietary tests with malathion conducted by USFWS laboratories are tabulated in table 16 below.

Table 16. Avian Subacute Dietary Toxicity

Species	% a i	LC50(ppm)	Toxicity Category	MRID	Author	Classi-fication
Ring-necked pheasant	95	8D LC_{50}=2639 (2220-3098)	Slightly toxic	00022923	Hill, E.F. et al USFWS, 1975	Core
Bobwhite quail	95	8D LC_{50}=3497 (2959-4011)	Slightly toxic	00022923	Hill, E.F. et al USFWS, 1975	Core
Japanese quail	95	8D LC_{50}=2962 (2453-3656)	Slightly toxic	00022923	Hill, E.F. et al USFWS, 1975	Supple-mental
Mallard duck	95	8D LC_{50}>5000	Nearly non-toxic	00022923	Hill,E.F. et al USFWS, 1975	Core

Based on the test results reviewed to date malathion displays low toxicity to 4 avian species on a subacute dietary basis. These studies were not submitted or funded by the registrant, but were conducted at the Patuxent Wildlife Research Center by U.S. Fish and Wildlife Service researchers. These studies are considered acceptable by the Agency and fulfill 71-2 guideline requirements.

2. Birds, Chronic

Avian reproduction studies using the TGAI are required for malathion because the following conditions are met: (1) birds may be subject to repeated or continuous exposure to the pesticide, especially preceding or during the breeding season, and (2) information derived from mammalian reproduction studies indicates reproduction in terrestrial vertebrates may be adversely affected by the anticipated us of the product. The preferred test species are mallard duck and bobwhite quail. Results of these tests are tabulated below.

Table 17. Avian Reproductive Sensitivity

Species	%ai	LOEL Effected Parameters	NOEL	MRID	Author	Classi-fication
Bobwhite quail	96.4	21WK LOEL=350 ppm -regressed ovaries and reduced egghatch At 1200 ppm- reduced shell thickness, # eggs layed , egg viability	110 ppm	43501501	Beavers, J. Wildlife Intl.,1995	Core
Mallard duck	94.0	20WK LOEL =2400 ppm Growth and viability	1200 ppm	42782101	Biolife Assoc. 1993	Core

The guideline (71-4) is fulfilled by the studies above. Chronic exposure to malathion in diets produced moderate toxicity to terrestrial avian species and low toxicity to waterfowl species tested to date. At food exposure concentrations of 350 ppm female bobwhite quail exposed to malathion for 10 weeks displayed regressed ovaries and abnormally enlarged/flaccid gizzards. A reduction in numbers of eggs hatched from eggs set was observed at 350 ppm. Reduced egg production , viability of eggs, and embryo survival as well as an increase in the number of cracked eggs (a possible indication of the weakening of the shell structure) was observed at 1200 ppm.

Non Guideline Laboratory Studies with Avian Species

Malathion - Induced Teratisms in the Developing Chick. Greenburg, J. and. N. Latham, 1968. University of Ottawa.

Methods: Fertile white leghorn chicken eggs were injected via small holes in the end of the shell with 0.1 ml solution of malathion in corn oil using a 20 gauge 1 inch needle. A single injection was administered to eggs at various stages of development (4-12 days incubation time)

Results: 0.1 ml of solution injected into Leghorn Chicken eggs proved lethal to 50% of the embryos after 7 days (dependent on age). 4-5 days embryos were most susceptible. Abnormalities included lack of feathers, smaller size, beak, plumage and hind limb defects.

In other studies where malathion was injected into eggs at 50 mg/egg chicks showed shortening of legs and bleaching of feathers (Marliac and Mutchler, 1963). For hen eggs injected with 25, 100, 200, 300, 400, and 500 ppm of malathion dissolved in acetone hatchability was significantly reduced at higher levels with hatches of 85%, 87%, 62%, 71%, 42%, and 6%, respectively (Dunachie and Fletcher, 1969). A number of studies were conducted where malathion or malaoxon were injected into chick embryos (Walker, 1971 and Khera and Lyon, 1968). Malaoxon caused reduced survival of embryos at a concentration of 30 micromoles, and those that did survive had severe abnormalities. Malathion at 15 micromoles produced less severe abnormalities.

Field Observations of Effects to Birds from Use of Malathion

The Ecology of a Small Forested Watershed Treated with the Insecticide Malathion S^{35}. S.Giles, Robert H., Jr., 1970, Published by the Wildlife Society.

Methods: Aerial Application - 2 adjoining Ohio watersheds were observed - with one treated and the other untreated. Malathion was radio tagged with Sulfur 35 radio nuclide. Two 20 acre watersheds were selected for comparison and were primarily deciduous forests. Application rate was 2 lbs/acre and 4 applications were made. Spray residue cards were placed under application areas for residue analysis. Residue collection discs were also suspended above the canopy using helium filled balloons. Glass discs were placed in the trees as well as the shrubs and in soil/litter surfaces.

Summary of Results: (Note; this was a very extensive study and the summary only briefly touches on actual amount of reported data).
Vegetation: Radioactivity was high in the tissues of plants sampled in the treated areas indicating active systemic uptake of malathion. New shoots and leaves showed especially high levels of radioactivity. Metabolites of malathion showed up in new stem and leaf growth up to one year after application.
Bacteria and soil fungi population: No effects observed. Fungi had higher concentrations of radioactivity than surrounding plant tissues.
Soil micro arthropods: Briefly affected.
Earthworms and Snails: No statistically significant effects observed in natural populations. No radioactivity was measured in snail tissues. However, in experimental cans containing soil and earthworms, more dead earthworms were found in the treated plots and several had radioactivity within their tissues suggesting uptake of the radio labeled malathion.
Fish and Crayfish: Stream samples showed no significant effects to mudminnows or blacknose dace. However, effects to brook sticklebacks, which appeared more sensitive, were extensive with over 95% mortality in the treated area. Caged crayfish appeared unaffected.
Insect numbers (all observed species): Greatly reduced, but populations recovered quickly. In stream nets located at temporary dams dead insect numbers were 1270 1 hour after spraying and decreased to 640 and 598 individuals collected 2 and 3 hours after spraying, respectively.
Reptiles and Amphibians: No effects noted - Toads adsorbed high loads of residues into tissues. However the route of intake of residues was not certain (skin adsorption, ingestion, etc)
Birds: Showed some reaction up to 48 hours post application, but no lasting effects noted. Lack of singing was observed throughout treated areas immediately after application and persisted for 2 days. By day 4 singing intensity was equal in treated and control areas. Possible explanations include sublethal insecticidal response, behavioral response due to loss of food, or possibly temporary emigration from the treated areas. Some radioactivity was detected in collected bird's whole organ tissues. Insectivorous birds had the highest detection of radioactivity on feathers.
Mouse, shrew and chipmunk populations: Up to a 45% reduction in population of white footed mice *Peromyscus leucopus novaboracensis* was estimated for the treated areas, based on pre and post treatment trapping counts. No difference in populations of short-tailed shrews or black-tailed shrews was determined, though residues were detected in costal cartilage, kidney, and heart tissues samples. Chipmunk populations were reduced 55% in treated areas following applications. The study author concludes "As with the mice this is not a lethal effect, but apparently one of productivity and survival."
Large mammals: Appeared unaffected.

Use of Enzyme Profiles to Monitor Residues in Wildlife. Dieter, Michael P., 1975 USFWS, Patuxent Wildlife Research Center.

Methods: Starlings were fed varying concentrations of various pesticides and plasma enzyme levels were measured.
Results: Starlings fed 160 ppm of malathion for 12 weeks showed 30% decrease in AChE and 50% decrease in 1 acetate dehydrogenase activity.

Effects of Ultra-Low Volume Applications of Malathion in Hale County Texas Hill, Elwood F. et al., 1971. Journal of Med Entomology

Methods: A number of field observations were recorded following 9 ULV aerial applications of malathion over Hale County by C123 cargo planes for mosquito control. During this operation nontarget insects and wildlife were also monitored for possible adverse effects. Nontarget insects wer sampled twice weekly using sweep nets and traps (vehicle mounted). House sparrows and other species were surveyed, particularly insectivorous species. 116 sparrows were banded prior to spraying in Plainview, Texas. Carcass searches were also conducted post application. AChE levels were determined in the sparrows prior to spraying and 30 hrs. following applications 1, 3, 5 and 7. Diptera, Hemiptera, and Coleoptera were main insect groups collected in sweep nets and traps.
Results: Only 9.5% of the banded sparrows (11 of 116) were recaptured. No bird carcasses were recovered. Brain AChE levels in the captured sparrows were not significantly inhibited - but a slight reduction from 0.023 to 0.018 was observed. Unprotected honeybees were killed, but covered hives were not seriously effected.

Acute Toxicity of Dieldrin and Malathion to Wild Sharp-tailed Grouse. McEwen, Lowell and Robert L. Brown. Journal of Wildlife management. Vol. 30, No. 3, July 1966. MRID 113233

Methods: 52 live trapped grouse from Montana were given oral doses of dieldrin, malathion, and lactose (controls) and released after tagging. They were subsequently observed by capture or radio tracking.
Malathion Results: The lethal dose of malathion was observed to occur between 200-240 mg/kg. Reaction to malathion occurred within 72 hours - either death or full recovery. Sublethal signs include depression, slow reactions, blinking, head nodding, and eventual heart or respiratory failure. Radio tracked grouse displayed normal to severe reactions once released. 8 of 12 birds were recovered. Predators are suspected in the disappearance of unrecovered birds (in one case a bird moderately dosed with dieldrin was confirmed killed by a coyote). Grouse that were dosed carried transmitters up to 12 days after release. All confirmed predator kills had received what were considered sublethal doses of the test material. Other birds were discovered to have been attacked and injured. The radio transmitters did not hinder all birds as many were recovered in healthy condition. The sublethal effect of the malathion and dieldrin are suspected. All controls survived and successfully bred.

Physiological Effects of Malathion on the House Sparrow *Passer domesticus*. Mehrotra, K. N. et al, 1966. Indian Agricultural Research Institute Delhi, India.

Methods: Birds were offered treated grain with 5% ai malathion dust. (Concentration 56.7g/56.8 kg of grain or approximately 100 ppm) to determine deterrent effect. Oral doses were administered at 1,2,5 and 10 mg/bird in acetone or approximately 50, 100, 250, and 500 mg/kg based on mean avg wt.

Results: Sparrows showed 75% reduction in feeding on treated seed vs. untreated seed(4 grams of treated seed consumed vs 21 gms. of untreated seed on average). Orally dosed birds showed increased respiration, head droop, ejection of white fluid from mouth, chronic and tonic convulsions at 5 mg/kg or more. Birds that did recover did so in about 1 hour. AChE inhibition was 83%, 75%, 50% and 25% at 19 mg, 5 mg, 2 mg and 1 mg per kg of body weight, respectively within 5 minutes of ingestion. The 1 and 2 mg/Kg dosed birds recovered in 24 hours. 57% and 18% mortality was observed at 10 and 5 mg/kg feed residue concentrations.

The Effects on Quail, Migratory Birds and Non-Game Birds from Application of Malathion and Other Insecticides. Parsons, Jack K. and Billy Don Davis, Texas Parks and Wildlife Dept., 1971. Study conducted from 1964 to 1968.

Methods: During bollweevil control programs on cotton game and nongame bird populations near cotton fields were observed. Applications was aerial at 12 to 16 oz. (approx. 1.2 lb ai) of technical malathion per acre. Up to 7 applications were made at 5-22 day intervals. Sites were <160 acres with one site containing a lake where waterfowl visited. Caged quail were placed in fields in four groups each containing 10-12 birds each. Birds were aged and weighed. Once birds were exposed to spray they were returned to a lab shelter area. Exposed feed and insects were fed to the test birds. Thorough carcass searches were made 24 hours after spraying occurred.
Results: No major differences in weight gain were noted between treated and control birds. No toxicant related mortality was noted after 3 application of malathion. No dead birds were located adjacent to fields. Sublethal indicators other than weight were not measured (e.g. AChE levels).

Brain Cholinesterase Activity in Birds After a City-Wide Aerial Application of Malathion. Kucera, Emil. Manitoba Dept. of Environment and Workplace Safety and Health. 1987.

Methods: Aerial application of malathion was made over Winnipeg in July 1983 after health officials determined that there was concern for possible outbreak of equine encephalitis from mosquito population increases. Malathion was applied as ULV solution using 95% malathion. Application rate was 210 ml/ha over the entire city to control mosquitos. House sparrows and pigeons were monitored for AChE levels prior to spraying and post application. Dead birds were also analyzed when reported to the researchers by the public. 20 caged sparrows were placed in a local park where application was made.
Results: Actual deposition rate for sprayed area was 140 ml/ha. and the area was monitored for 3 hours post application. 41 sparrows and 39 pigeons were collected within 2 weeks of spraying. Caged exposed sparrows were sacrificed and examined as well. No significant differences were noted (6-12% variation) in AChE levels of post spray--to prespray birds. Some reservation is expressed that study birds may all have been exposed to ground fogging applications prior to aerial application exposure.

Fluctuations in Bird Populations on the Island of Bota as Related to an Experimental Program to Control The Melon Fly. John Engbring, 1989. U.S. Fish and Wildlife Service, Honolulu, Hawaii.

Methods: An experimental program to control melon flies on the Island of Bota in the Northern Marianas Islands, provided the USFWS with an opportunity to monitor avian populations while subjected to exposure to malathion laced bait sprays (Cue-lure) that were aerially applied. Survey stations were established at 164 locations 150 meters apart in 8 different transects located on back roads adjacent to forested/semi-forested areas. 8 minute counts were conducted at each station within 4 hours of sunrise before, during, and after the application of the pesticide baits. A total of 1,169 eight minute counts were made, 368 in Aug. 1988, 432 in December 1988, and 369 in Aug. 1989. Applications were made at 3 week intervals beginning in Oct. 1988 at up to 5 -30 gms/hectare depending on bait type.
Results: Of the 10 native species counted 5 increased in number and 5 decreased. The author was not certain if this was a normal annual fluctuation or one caused by pesticides. Populations of the white throated ground dove, the Phillipine turtle dove, and possibly the bridled white eye were significantly lower in the following year. No acute mortality was reported. The other 20 native species were observed and populations appeared unaffected. Even insectivorous species did not appear to suffer population decreases.

Mammals, Acute and Chronic Toxicity

Wild mammal acute toxicity testing is required on a case-by-case basis, depending on the results of lower tier laboratory mammalian studies, intended use pattern and pertinent environmental fate characteristics. In most cases, rat or mouse acute toxicity values are obtained from the Agency's Health Effects Division (HED) and substitute for wild mammal testing. These toxicity values are reported below.

Table 18. Mammalian Acute Oral and Chronic Dietary Toxicity

Specie	%ai	LD50 (mg/Kg)	Study ID	NOEL (parameter)	Study ID and Author	Cate-gory
Mice	Tech 90%	720-886	Doc #000389	500 ppm (growth -2 yr. chronic study)	Reference Doc#000389 N.C.I.,1979	N.R.
Guinea pig	Tech	570	Doc # 000389	Not determined	Reference Doc#000389 Pham.Exp.Ther. 12:327,1953	N.R.
Sheep	Tech	<150	Doc # 000389	Not determined	Reference Doc# 000389 J.Vet.Am.Medical Ass., 1957	N.R.

Cow	95%	560(adult) 80 (calf)	Doc # 000389	Not determined	Ref Doc # 000389 Golz and Shaffer, 1956	
Cat	Tech	>500	Doc # 000389	Not determined	Reference Doc# 000389	N.R.
Rat (Wistar albino)	57% EL	1763	Doc # 000317	ataxia, tremors, salivation, diarrhea observed	Reference Doc#000317 Doc# 000389	Suppl.
Rat	Tech	390-2100	Doc # 000389 Am. Cyanamid 1956	1000 ppm (growth) 32 day ChE reduction at 100 ppm 240 mg/kg/day reduced pup survival and BW	Reference Doc#000389 Karlow and Martin , 1965	N.R.
Rabbit	Tech	>900	Doc# 000389, J. Econ. Entomol. 48:139	50 mg/kg/day resorption of embryos	MRID 260123 Ref.Doc.#000389 Food and Drug Research Lab,1984	N.R

In one rat study oral LD50 ranged from 1000 to 1845 mg/Kg with females being more sensitive than males.

The results of mammalian laboratory indicate that malathion is slightly toxic to mammals on an acute o basis. Sublethal effects may occur at concentrations as low as 100 mg/Kg for certain species. Reproductive effects are not expected unless concentration remain at 500-1000 mg/Kg for extended periods of time.

Non Guideline Studies with Mammals

Toxicity of Malathion to Mammals, Aquatic Organism and Tissue Culture Desi, I. et al 1976.

Results: In white rats alteration of EEG (elevated excitability of nervous system) at 75 and 438 mg/kg, and reduced acetocholinesterase levels were observed. The test rats exposed to malathion showed a reduced ability to run a maze with increased numbers of errors.

Comparative Metabolism of Malathion - C_{14} in Plants and Animals. Bourke, J.B. et al New York State Agricultural Experiment Station, Cornell University, 1968.

Methods: Red Kidney bean plants were exposed to radio labeled malathion solution by passing air over foliage for 20-30 minutes (with solution mixed into air stream) C^{14} was traced in tissues of plants for 14 days. Various intermediates (metabolites) were deposited within tissues. Rats were treated wit malathion via oral ingestion.

Results: Plants appeared to store various metabolites in tissues whereas the rats began excreting the radio labeled malathion in their urine within 2 hours after ingestion. By 24 hours 83.4% of the radio labeled material was excreted in the urine.

In the 1970 study by R.H. Giles (see previous summary) certain species of small mammals (white-footed mice and chipmunks) showed significant population reductions (30-55%) after treatment of a forest area with 2 lb ai/A of malathion. Larger mammals and interestingly, shrews which are often sensitive due to high metabolisms, were not observed to have been effected. Population reductions were not observed to be related to acute adult mortality, but rather to reduced reproductive success or possibly effects on survival of young.

Nontarget Reptile Toxicity

The Agency has not reviewed extensive laboratory toxicity data pertaining to toxicity of malathion to reptiles. In general, the Agency uses avian toxicity thresholds in the determination of hazard to reptiles One study was found regarding acute effects to the Carolina anole and another study which indicated possible effects to developing embryos of snapping turtles.

Responses of the Iguanid Lizard, *Anolis caroleninsus* to Four Organophosphorous Pesticides, Hall R.J. and D.R. Clark, 1982. Environmental Pollution (Ser. A) 28:45-52
Methods: Oral ingestion of organophosphate pesticides and the resulting percent mortality was measured for Carolina anoles.
Results For malathion the acute LD50 was determined to be 2324 mg/Kg

Teratogenic Effects of Malathion and Captan in the Embryo of Common Snapping Turtle. Mitchell and Yutema, 1973.
Results: Observations of the abnormal development in of embryos of the common snapping turtle exposed to malathion is summarized.

Non-target Beneficial Insect Toxicity

Terrestrial Insects
A honey bee acute contact study using the TGAI is required for malathion insecticide products because uses will result in honey bee exposure. A honey bee foliar residue contact toxicity study is required using the typical end-use product because many uses will result in potentially adverse honey bee exposure to vegetative surfaces after application. Results are tabulated below.

Table 19. Nontarget Pollinator Insect Acute and Foliar Contact Toxicity

Species	%ai	LD50 (ug ai/Bee)	Toxicity Category	MRID	Author/ year	Classification
Honey bee	57EC	8 HR Foliar Contact LD_{50} <1.6	Highly toxic	41208001 41284701	1989	Core
Honey bee	Tech	48 HR LD_{50} =0.20	Highly toxic	05001991	1978	Core
Honey bee	Tech	96 HR LD_{50} =0.709	Highly toxic	0001999	1967	Core
Honey bee	Tech	N.R. LD_{50}= 0.27 (0.22-0.29)	Highly toxic	05004151	1968	Core
Honey bee	Tech	48 HR LD_{50} =0.38	Highly toxic	05004003	1968	Core

The results indicate that malathion is highly toxic to bees on an acute contact basis either through exposure to direct spray or through foliar residue contact within 8 hours after spray is applied. The guidelines 141-1 and 141-2 are fulfilled by these studies.

Toxicity to Terrestrial Insects with Aquatic Lifestages

Though not required, a number malathion studies on toxicity to aquatic insect larvae conducted by the U.S. Fish and Wildlife Service laboratories were reviewed. These studies are indicative of possible population effects to species of insects which spend the early stages of their lives as aquatic larvae. Many of these species form important links in the food chain for insectivorous birds, mammals, fish, amphibians and reptiles as well as predatory aquatic and terrestrial invertebrates.

Table 20. Toxicity to Aquatic Larvae of Terrestrial Insects

Species	% ai	LC_{50}(C.L.s) in PPB	Toxicity	MRID	Author/Year	Classifi-cation
Stonefly *Claasenia sabulosa*	95%	LC50=2.8 (1.4-4.3)	Very high	40098001	Mayer and Ellersieck, USFWS, 1984	Supplemental
Stonefly, *Pteronarcella badia*	95%	LC_{50}=1.1 (0.78-1.5)	Very high	40098001	Mayer and Ellersieck, USFWS, 1984	Supplemental
Stonefly, *Isoperla* sp.	95%	LC_{50}=0.69 (0.2-2.4)	Very high	40098001	Mayer and Ellersieck, USFWS, 1984	Supplemental
Damselfly, *Lestes congener*	95%	LC_{50}=10 (6.5-15.0)	Very high	40098001	Mayer and Ellersieck, USFWS, 1984	Supplemental
Caddisfly, *Hydropsyche* sp.	95%	LC_{50}=5.0 (2.9-8.6)	Very high	40098001	Mayer and Ellersieck, USFWS, 1984	Supplemental

Caddisfly, *Limnephalus* sp.	95%	LC_{50}=1.3 (0.77-2.0)	Very high	40098001	Mayer and Ellersieck, USFWS, 1984	Supplemental
Snipefly, *Atherix variegata*	95%	LC_{50}=385 (245-602)	High	40098001	Mayer and Ellersieck, USFWS, 1984	Supplemental

Based on the data reviewed to date for aquatic early life stages of terrestrial non-target insects malathion is classified as highly to very highly toxic to larvae of these species, and thus, their successfu reproduction and survival to adult stages.

Field Observations of Effects to Non-Target Insects

Over it's long history a great amount of field testing has been conducted with Malathion products in fie test situations by agricultural research laboratories, registrants, and government research laboratories. A number of these studies are briefly summarized below along with results that were reported from exposure to malathion to a variety of terrestrial species.

California Medfly Report. Oshima, R. S. 1982

Methods: During a six week period - baited sprays were applied with large droplet sizes (200-300 *mu* mean diameter).
Results: Malathion and malaoxon were detected in water throughout monitoring period. Rain runoff to storm drains produced concentrations up to 583 ppb in existing streams. Since bait sprays did not attract honeybees it was believed that they would be unaffected. However, nontargeted lacewings and dipterids were attracted (mainly scavenger flies) to the bait and killed.

Impact of Mediterranean Fruit Fly Malathion Bait Spray on Honeybees. Gary, Norman E. and Eric C., Mussen, Dept. of Entomology, Univ. of California, Davis 1984.

Methods: The application rate was 175.4 ml malathion technical and 701.8 ml Staley's Protein Bait/hectare applied weekly at predawn in San Francisco Bay area. 48 commercial honeybee colonies were distributed evenly to 4 apiaries-two inside spray zone. Control colonies were located at 5 km and 9 km outside spray zone. Bodies were collected daily at hive entrances. Pollen samples also were taken daily. A similar study was conducted in Stockton, CA. with one apiary located inside the spray zone and one control placed 5.7 km outside spray zone. Each apiary in the Stockton study contained 10 bee colonies.
Results: Significant mortality was observed 48 hours following each application. Cause was determined to be pesticide contaminated pollen (2.06 ppm (mean)) and body residue levels of 0.9 -5.3 ppm. Data from Stockton study also showed increased mortality which was partially attributable to nearby application of Sevin, (alfalfa fields), Kabbate and sulfur dust (tomato fields). Reduced flight activity was observed at both exposed sites after pesticide applications. Other mortality may have occurred in the fields (not measurable).

Effects of Malathion Bait Spray for Mediterranean Fruit Fly on Non-target Organisms on Urban Trees in Northern California. Dahlsten, Donald L., University of California, 1983.
Methods: Protein hydrolysate bait spray and malathion applications were monitored. The study measured effects to nontarget beneficial insect predators common in urban trees. Drop cloths were placed under trees and dead fallen insects were collected and identified. 3 Trees were chosen randomly in each of the selected spray areas. 2 trees were chosen in control plots. 2 drop cloths were placed under each tree. Test site locations were in Pleasanton, CA and Woodside, CA.
Results: 17 species of aphids, numerous dipterids, butterfly (lepidoptera) larvae, spiders, cynipoidea, and hemiptera appeared to be heavily effected. Also pscoptera were reduced.

Effects of Ten Organic Insecticides on Two Species of Stonefly Naiads. Jensen, Loren D. and Anden R. Gaufin, Dept. Zoology, University of Utah, 1964.(MRID 00065497)

Methods: The 96 hour acute exposures under static conditions included malathion exposure.
Results: Even when the naiads were removed after displaying sublethal effects (convulsions or tremors and placed in clean water, they generally died within 24 hours.

Bee Poisoning Hazard of Undiluted Malathion Applied to Alfalfa in Bloom. Johansen, C.A. et al. Washington State University College of Agriculture. 1965.

Methods: Six colonies of honeybees were placed in a 125 acre alfalfa field 36 hours before aerial application. 2 hives were covered with wet burlap during application and burlap was removed 24 and 48 hours post application. Two hives were left uncovered in the sprayed fields. 2 other colonies were placed 2.25 miles from the application site and one of these was covered with burlap for 48 hours. 8 fluid oz of malathion ULV concentrate was applied per acre by aerial spray at 50 feet altitude in a 125 foot swath on Aug 14. Package bee cages (150-200 bees) were also placed in fields 2 and 7 hours after application for a 3 hour exposure period. Caged bees were also exposed to foliar residue samples at intervals following the application.
Results: Bee mortality was higher than normal for 4 days after application. Those covered with wet burlap suffered the highest mortality 1 day after the covers were removed. Bees caged on treated foliage also exhibited higher than normal mortality. Check (control) colonies showed between 500 and 838 dead bees at hive entrances. Treated hive mortalities ranged from 1298 ((unprotected) to 2582 (entrance covered) honeybees. Bees which contacted treated foliage showed from 100% (2 hours-1 day post application) mortality to 14% mortality (4 day old residues) versus an average of 5% mortality for control bees. Malathion residues on foliage ranged from 28.8 ppm at application to 0.4 ppm 14 days after application. Residues remained over 25 ppm for 4 days following application after which a rainfall event occurred. Grasshopper populations were greatly reduced from 12/sq. yd. to less than 1/sq yd. three days after treatment. Lygus bugs were also controlled for up to 3 weeks. Interestingly, the target organisms, Alfalfa weevils and larvae, were not totally controlled. Lady beetles populations were reduced for up to 3 weeks following applications.

Terrestrial Wildlife Field Incidents

The Agency reviews and records all wildlife mortality incidents reported independently or under 6a2 provisions of FIFRA regarding use of pesticides or pesticide mixtures. These incidents are reported to the Agency by a variety of sources including registrants, private organizations and local, state, or federa agencies. A summary of all terrestrial incidents reviewed by the Agency following use of malathion products or mixtures is provided in table 21 below.

Table 21

Location and Date	Incident	Description	Probability
Oregon, 1/1/85	I000130	5000 acres of alfalfa treated with malathion by USDA-extensive mortality of honeybees collecting nectar from blossoms reported	Probable
Florida, 1997 Medfly Program, Hillsborough County area	USDA Medfly Incident Report	Three incidents involving mortality of ducks were reported along with over 40 fish kills that were investigated. All occurred where malathion bait formulations were used near ponds. 6/22-10 to 14 Ducks killed-Seminole Hts.-baits used 6/14-Duck kill-NW Hillsborough sector-baits used 6/25-Duck kill-Rodrie pond-baits applied aerially	Possible- but unlikely. Only routes believed to offer logical exposure route- oral ingestion of baits or dermal exposure-residue concentration too low to =LD50.

The incidents where duck mortality was reported in Florida medfly program investigations were determined to be more likely caused by some other toxicant. Though fish kills did occur in the ponds, actual residues were well under those which would be expected to cause oral toxicity in mallard duck(1485 mg/Kg). In the case of the June 14 fish kill an oily substance was observed on the moribund ducks. Park service personnel had also sprayed herbicides near the pond (Glyphosate and Copper). Maximum malathion concentration on vegetation was only 3.0 ppm far below avian toxicity thresholds. The Agency would tend to agree with USDA that malathion was not the primary cause of death in the duck kill incidents.

Acute Toxicity to Fish

Two freshwater fish acute toxicity studies using the TGAI are required to establish the toxicity of a pesticide to freshwater fish. The preferred test species are rainbow trout (a coldwater fish) and bluegil sunfish (a warmwater fish). Acute toxicity testing with estuarine/marine fish species using the TGAI is required for malathion because the end-use product is intended for direct application to the marine/estuarine environment and the active ingredient is expected to reach this environment because (its use near estuarine environments. The preferred estuarine test species is sheepshead minnow. Results of numerous tests reviewed by EPA are summarized below.

Table 22. Freshwater(FW) and Marine/Estuarine(SW) Fish Acute Toxicity

Species Tested	% ai	LC50 and CLs in PPB	Toxicity	MRID	Author	Classi-fication
Freshwater Fish Species						
Bluegill sunfish(FW)	95	96 Hr LC_{50}=20 (16-25)	Very High	40098001	Mayer and Ellersieck, USFWS, 1984	Core
Redear sunfish(FW)	95	95 Hr LC_{50}=62 (58-67)	Very high	40098001	Mayer and Ellersieck, USFWS, 1984	Core
Rainbow trout(FW)	95	96 Hr LC_{50}=4 (2-7)	Very high	40098001	Mayer and Ellersieck, USFWS, 1984	Core
Yellow perch(FW)	95	96 Hr LC_{50}=263 (205-338)	High	40098001	Mayer and Ellersieck, USFWS, 1984	Core
Largemouth bass(FW)	95	96 Hr LC_{50}=250 (229-310)	High	40098001	Mayer and Ellersieck, USFWS, 1984	Core
Carp(FW)	95	96 Hr LC_{50}=6590 (4920-8820)	Moderate	40098001	Mayer and Ellersieck, USFWS, 1984	Supl.
Fathead minnow(FW)	95	96 Hr LC_{50}=8650 (6450-11500)	Moderate	40098001	Mayer and Ellersieck, USFWS, 1984	Core
Channel catfish(FW)	95	96 Hr LC_{50}=7620 (5820-9970)	Moderate	40098001	Mayer and Ellersieck, USFWS, 1984	Core
Coho salmon(FW)	95	96 Hr LC_{50} 170 (160-180)	High	40098001	Mayer and Ellersieck, USFWS, 1984	Core
Cutthroat trout(FW)	95	96 Hr LC_{50}=174 (112-269)	High	40098001	Mayer and Ellersieck, USFWS 1984	Core
Brown trout(FW)	95	96 Hr LC_{50}=101 (84-115)	High	40098001	Mayer and Ellersieck, USFWS, 1984	Core
Lake trout(FW)	95	96 Hr LC_{50}=76 (47-123)	High	40098001	Mayer and Ellersieck, USFWS, 1984	Core
Black bullhead catfish(FW)	95	96 Hr LC_{50}=11700 (9600-14100)	Moderate	40098001	Mayer and Ellersieck, USFWS, 1984	Core
Green sunfish(FW)	95	96 Hr LC_{50}=1460 (900-2340)	Moderate	40098001	Mayer and Ellersieck, USFWS, 1984	Core
Walleye(FW)	95	96 Hr LC_{50}=64 (59-70)	Very high	40098001	Mayer and Ellersieck, USFWS, 1984	Core
Tilapia(FW)	95	96 Hr LC_{50}=2000 (N.R.)	Moderate	40098001	Mayer and Ellersieck, USFWS, 1984	Core

Goldfish(FW)	95	96 Hr LC_{50}=10700 (8340-13800)	Moderate	40098001	Mayer and Ellersieck, USFWS, 1984	Core
Estuarine Marine Fish Species						
Spot(SW)	95	Flowthrough 48 Hr LC_{50}=320(N.R.)	High	40228401	F. L. Mayer, USEPA	Supl.
Striped mullet(SW)	95	Flowthrough 48 Hr LC_{50}=330(N.R.)	High	40228401	F. L. Mayer, USEPA	Supl.
Longnose killifish(SW)	95	Flowthrough 48 Hr LC_{50}=150(N.R.)	High	40228401	F.L. Mayer, USEPA	Supl.
Sheepshead minnow(SW)	95	Flowthrough 96 HR LC_{50}=33.0(14-63)	Very high	41174301	Bowman, J 1989, ABC Laboratories	Core
Striped bass(SW)	95	96 Hr LC_{50}=60(N.R.)	Very high	156311	Wellborn, T. 1971 Reference	Supl.
Sheepshead minnow(SW)	57 EC	96 HR LC_{50} 55	Very high	41252101	Bowman,J. ABC Labs, 1989	Core

Based on the extensive data reviewed for malathion toxicity to freshwater and estuarine/marine fish the pesticide is classified as very highly to moderately toxic to fish dependent on the sensitivity of the test species. In many cases these studies were done with static test systems, no measured concentrations, and varying pH levels which can influence the actual toxicity or calculation of toxicity values for a chemical with fate characteristics such as malathion. This is due to the hydrolytic instability of the compound. Thus , actual mean concentrations which caused the mortality may have been much lower after 96 hours of exposure than is indicated. This would have influenced the calculation of LC50 levels if they had been based on measured concentrations instead of nominal 0 hour concentrations. The 72-1 and 72-3 guidelines for acute toxicity testing of fish are fulfilled by the data reviewed above.

Chronic Toxicity To Freshwater and Estuarine Fish

A freshwater fish early life-stage test and/or an estuarine fish early life stage test using the TGAI is required for malathion because some end-use products may be applied directly to water and other product uses are expected to contribute residues which may be transported to water from the various intended use sites. In addition the following chronic testing guideline conditions are met: the pesticide intended for use such that its presence in water is likely to be recurrent, aquatic acute LC50 are less than 1 mg/l, the EECs in water are equal to or greater than 0.01 of any acute LC50, studies of other organisms indicate the reproductive physiology of fish may be affected. The preferred test species are the rainbow trout and the sheepshead minnow.

A freshwater fish full life-cycle test using the TGAI is required for malathion because the end-use product is intended to be applied directly to water and is expected to be transported to water from the intended use sites. In addition, the following conditions were met: the EEC is equal to or greater than one-tenth of the NOEL in the fish early life-stage or invertebrate life-cycle test, and studies of other organisms indicate the reproductive physiology of fish may be affected. The preferred test species is fathead minnow. A satisfactory full life cycle test has not been submitted, though a pilot lifecycle stud with fathead minnow has been attempted. Results of this test are tabulated below.

An estuarine/marine fish early life stage or life-cycle test using the TGAI is required for malathion due the application of malathion for mosquito and medfly control near estuarine habitats and use on crops associated with areas near these habitats. This study may be waived if further modeling results indicate that EEC levels in estuaries will not exceed the early life stage NOEC levels for a freshwater species, o if the registrant does not continue to support these uses. The preferred test species is sheepshead minnow.

Table 23. Freshwater and Marine Fish Chronic Toxicity Test Results

Species	Guide-line	% a i	LOEC in PPB	NOEC	MRID	Author	Cate-gory
Rainbow trout	72-4	94	97 day LOEC= 44	2 PPB	41422401	Cohle P., ABC Laboratories 1989	Core
Flagfish, *Jordanella floridae*	72-4	tech	110 day LOEC=11	8.6 PPB	Reference	Hermanutz,R., 1978*	Supple-mental
Fathead minnow	72-5	tech	158 day LOEC=350	N.D.	D234663	ABC Laboratories, 1997	Supple-mental

The guideline (72-4) is fulfilled for freshwater fish.
The guideline (72-4) is **not** fulfilled for a marine/estuarine fish species.
The guideline (72-5) is **not** fulfilled. Study aborted early due to malathion degradation problems.

* Hermanutz, R. 1978. Endrin and Malathion toxicity to Flagfish (*Jordanella floridae).* Arch. Of Environmental Contaminants and Toxicology 7:159-168

Toxicity of Malathion to Amphibian Lifestages

Though extensive literature has not been reviewed for toxicity of malathion to adult or larval life stages of amphibians, there are data to suggest that malathion may have adverse effect to amphibian early life stages if environmental concentrations exceed 1 ppm. In studies with developing frog embryos, gross abnormalities in skeletal development were noted for tadpoles which had been exposed for several days to malathion concentrations ranging from 1 to 20 ppm. Abnormalities observed included spinal curvature, blister development, and abnormal swimming behavior at concentrations ranging from 5-10 ppm. At concentrations >10 ppm malathion was highly embryo-toxic.(author(unknown)Dept. Of Zoology, University of Poona, India, Bulletin of Environmental Contamination Toxicology, 31:170-176(1983) Please Note: reference unverified-internet article). Mayer and Ellersieck have listed the acute toxicity of malathion to tadpoles of Fowlers toad, *Bufo woodhousei*, and the chorus frog, *Pseudacris triseriata* to be 420 ppb and 200 ppb, respectively. These acute values are considered highly toxic.

Acute Toxicity to Freshwater and Marine/Estuarine Invertebrates

A freshwater aquatic invertebrate toxicity test using the TGAI is required to establish the toxicity of a pesticide to aquatic invertebrates. The preferred test species is *Daphnia magna*.

Acute toxicity testing with estuarine/marine invertebrates using the TGAI is required for malathion because the end-use product is intended for direct application to the marine/estuarine environment or the active ingredient is expected to reach this environment because of its use near estuarine habitats. The preferred test species are mysid and eastern oyster. Results of freshwater and estuarine invertebrate acute toxicity tests reviewed by the Agency are tabulated below.

Table 24. Freshwater and Marine /Estuarine Invertebrate Acute Toxicity

Species Tested FW=Freshwater SW=Marine species	% ai	EC50 or LC50 in PPB	Toxicity	MRID	Author	Classi-fication
Freshwater Invertebrate Species						
Water flea, *Daphnia pulex*(FW)	95	48 Hr EC_{50}=1.8 (1.4-2.4)	Very high	40098001	Mayer and Ellersieck, USFWS, 1986	Core
Scud, *Gammarus lacustris*(FW)	tech	48 Hr LC_{50}=1.8 (1.3-2.4)	Very high	05009242	FWS Laboratories, 1969	Core
Scud, *Gammarus fasciatus*(FW)	95	96 Hr. LC_{50}=0.5 (N.R.)	Very high	40098001	Mayer and Ellersieck, USFWS, 1986	Core
Daphnid *Simocephalus serrulatus*(FW)	95	48 Hr LC_{50}=0.69 (0.44-0.79)	Very high	40098001	Mayer and Ellersieck, USFWS, 1986	Supple-mental
Crayfish,*Orconectes nais*(FW)	95	96 Hr LC_{50}=180 (140-230)	High	40098001	Mayer and Ellersieck, USFWS, 1986	Supple-mental
Glass shrimp, *Palaemonetes kadiakensis*(FW)	95	96 Hr LC_{50}=12 (N.R.)	High	40098001	Mayer and Ellersieck, USFWS, 1986	Supple-mental
Seed Shrimp, *Cypridopsis vidua*(FW)	95	49 Hr LC_{50}=47 (32-69)	High	40098001	Mayer and Ellersieck, USFWS, 1986	Core

Water flea, *Daphnia magna*(FW)	57EC	48 Hr EC_{50}=2.2 (1.9-2.5)	High	410297-01	Burgess, D. ABC Labs, 1989	Core
Water flea, *Daphnia magna*(FW)	95	48 Hr EC_{50}=1.0 (0.7-1.4)	High	40098001	Mayer and Ellersieck, USFWS, 1986	Core
Sowbug, *Asellus brevicaudus*(FW)	95	96 Hr LC_{50}=3000 (1500-8500)	Moderate	40098001	Mayer and Ellersieck, USFWS, 1986	Supple-mental
Estuarine Marine Species						
Mysid, *Mysidopsis bahia*(SW)	94	96 Hr LC_{50}=2.2 (1.5-2.6)	very high	41474501	Forbis, A., ABC Lab.,1990	Core
Pink shrimp, *Penaeus duorarum*(SW)	95	48 Hr LC_{50}=280 (N.R.)	High	40228401	F.L. Mayer, USEPA, 1986	Supple-mental
Eastern oyster, *Crassostrea virginica* (SW)	95	96 Hr LC_{50}>1000	Not con-clusive	40228401	F.L. Mayer, USEPA, 1986	Supple-mental
Eastern oyster, *Crassostrea virginica*(SW)	57% EC	96 Hr EC_{50}=2960 (N.R.)	Moderate	42249901	Wade, B and J. Wisk, ESE , Inc. 1992	Core
Blue Crab, *Callinectes sapidus*(SW)	95	48 Hr LC_{50}>1000	Not con-clusive	40228401	F.L. Mayer, USEPA, 1986	Supple-mental

Since the LC50/EC50 values are in the range of 0.5 to 3000 PPB, malathion is classified as very highly to moderately toxic to aquatic invertebrates on an acute basis, dependent on the sensitivity of the tested species. Many of the studies above were conducted under static conditions with no measurement of actual residue levels. Thus, actual LC_{50} values might have been even lower than those reported if they had been based on measured concentrations (expected to be lower due to degradation). The guidelines 72-2 and 72-3 for invertebrate acute testing are fulfilled by these studies.

Chronic Toxicity to Freshwater and Marine Invertebrates

Freshwater and estuarine/marine aquatic invertebrate life-cycle tests using the TGAI is required for malathion since the end-use product may be applied directly to water or is expected to be transported to water from the intended use site, and the following conditions are met: (1) the pesticide is intended for use such that its presence in water is likely to be continuous or recurrent regardless of toxicity, (2) aquatic acute LC50 or EC50 are less than 1 mg/l, and (3) the EEC in water is equal to or greater than 0.01 of any acute EC50 or LC50 value. In addition, testing with other organisms indicate the reproductive physiology of invertebrates may be affected. The preferred test species are *Daphnia magna* for freshwater and *Mysidopsis bahia* for estuarine marine scenarios. Results of these tests are tabulated below.

Table 25. Freshwater and Marine/Estuarine Aquatic Invertebrate Life-Cycle Toxicity

Species	%ai	LOEC (parameter)	NOEC	MRID	Author	Classification
Water flea(FW)	94	21D LOEC= 0.10 PPB	0.006 PPB	41718401	Blakemore,G and D.Burgess, 1990	Core
Mysid(SW)		No Data				Required

The guideline (72-4) is fulfilled for freshwater species.
The guideline (72-4) is **not** fulfilled for estuarine species. A full life cycle study for mysid or other acceptable marine/estuarine species is required for the proposed uses of malathion.

Non Guideline Laboratory Studies with Aquatic Organisms

Acetylcholinesterase Inhibition in Federally Endangered Colorado Squawfish exposed to Carbaryl and Malathion Beyers, P. & P.Sikoski, 1993.

Methods: Squawfish were exposed for 32 days in flowthrough systems for the study of early life stage effects to this listed species. AChE inhibition was based on 24 hour exposure.
Results: AChE Activity NOEC=371 ug/L and LOEC=707 ug/l for malathion.

Acetylcholinesterase Inhibition in Federally Endangered Bonytail Chub Exposed to Carbaryl and Malathion. Beyers, P. (1993)

Methods: 32 day static renewal exposure and 4 day static renewal acute exposures employed.
Results: The NOEC for acetocholinesterase inhibition and reduced growth in the Bonytail chub was 990 ug/L. Threshold conc. = 521 ppb
For malathion the squawfish estimated LC_{50} = 9.14 ppm (8.3 - 10) nominal concentration. The Bonytail chub LC_{50} = 15.3 ppm(14.4 - 16.4) based on nominal concentrations. **Reviewers note:** The LC50 levels may have been lower if measured concentrations had been made and used in LC50 calculations. The second Beyers test also mentions an LOEC of 24.7 PPB for flagfish , *Jordanella floridae* in a previous 30 day exposure for survival/growth.

Chronic Toxicity of Malathion to the Bluegill (*Lepomis macrochirus*). Eaton, John G., 1970. Duluth EPA Lab., Duluth Minnesota.

Methods: Fish were wild caught from local ponds. The test fish were exposed at varying concentrations for over 8 weeks. Triton surfactant was added as solvent for stock solutions.
Results: Spinal deformation was observed at <10 ppb. MATC >3.6 <7.4 ppb All fish died at 80 and 40 ppb (within 16 days at 80 ppb and within 54 days at 40 ppb. Reproductive NOEC was <20 ppb. Survival and numbers of eggs produced/female were effected.

Sublethal Effects of Malathion to Three Salmonid Species. Post, George and Robert Leasure. Colorado State University, 1974.

Methods: Test material was 55% EC. Brook trout, rainbow trout and coho salmon were subjected to stamina flow tunnel tests after exposure to 40 - 300 ppb concentrations for 7-10 days. This type of test was used to imitate upstream migration .
Results: Coho salmon was the most sensitive species with AChE levels reduced 75%. The exposed fish were unable to perform 2/3 of work activity (swimming in current) as the unexposed fish. Possibl field effect=Less able to hunt, spawn or migrate upstream.

Toxicity of Malathion 500 to fall Chinook Salmon Fingerlings. Parkhurst, Zell and Harlan Johnson. USFWS, 1955 (Progressive Fish Culturist)

Methods: Fingerlings were exposed for 96 hours to concentrations of up to 240 ppb.
Results: LC_{50} =120 ppb after 96 hrs and 170 ppb after only 24 hours. 95% mortality after 24 hours at 240 ppb.

The Toxicity of the Hydrolysis and Breakdown Products of Malathion to Fathead minnow - Bender, Michael E., 1969. University of Michigan.
Methods: 96 hour static and 14 day flowthrough exposures
Results: Results demonstrated that diethyl fumarate was more toxic than the parent to this species and that synergistic effects occur between the parent and the two major degradates. Toxicity values for 4 confirmed and 9 proposed degradates to fathead minnow are provided. Diethyl fumarate LC_{50} = 4.5 mg/L. The LC50 for malathion to fathead minnow from Mayer and Ellersieck's publication is 8.65 mg/L.

Table 26. Toxicity of confirmed and proposed malathion degradates to fathead minnow.

Degradate	96 hour TLM in mg/L
Dimethylphosphorodithioic acid	23.5
Diethyl fumarate	4.5
2-mercaptodiethyl succinate	35.0
Dimethylphosphorothionic acid	42.5
Maleic acid	5.0
Diethyl maleate	18.0
Dimethyl phosphate	18.0
Dimethyl phosphite	225.0
Thioglycolic acid	30.0
Diethyl succinate	140.0
Diethyl dl-tartarate	650.0
Bis(hydroxymethyl) phosphinic acid	29.0

Ethylene phosphite	34.0

Uptake and Retention of Malathion by the Carp. Bender, Michael E. University of Michigan, 1969.

Methods: *Cyprinus carpio* used as test species. Fish were exposed for 4 days at 2.5 ppm.
Results: Liver, flesh, blood, gills and brain were areas of highest concentration (in that order).

The Toxicity of Malathion and its Hydrolysis Products to Eastern Mudminnow *Umbra pygmaea* Bender, Michael E., Virginia Institute of Marine Science, 1976.

Methods: Fish were exposed for 96 hour using static systems and 14 days using flow through systems. The fish were wildcaught. The laboratory used dechlorinated tapwater in 5 gallon tanks with 10 fish exposed/concentration. Five concentrations were tested.
Results: 2 mecapto diethyl succinate shown to be most toxic of 4 degradates tested to this species. (LC_{50} = 0.32 ppm). Diethyl fumarate LC_{50} = 1.47 ppm (was least toxic).

Abnormal Locomotion Associated with Skeletal Malformations in Sheepshead minnow. Weis, Peddrick and Judith Weiss, Rutgers University and New York Ocean Science Laboratory, Montauk, New York, 1975.

Methods: Embryos were exposed at 3 and 10 ppm with 25 eggs/concentration.
Results: Exposure appeared to produce skeletal malformations which impeded swimming ability of fry NOEC was 1 ppm. 25% and 41% of the larvae were effected at 3 and 10 ppm, respectively. Delayed hatch was observed in the 10 ppm test group.

Woodward, Dan F., Sport Fisheries Research USFWS publication 77, 1969.

Results: The study reports an observed loss of avoidance response in goldfish after 72 hr exposure to malathion at 1 and 5 ppm.

Quarterly Report - USFWS Research Laboratory, Columbia, Mo. 1967.

Results: Acute Toxicity Studies

1.3 gm Walleye LC_{50} = 62 ppb Raw water
0.9 gm Largemouth bass LC_{50} = 80 ppb raw water
1.4 gm - Bluegill LC_{50} = 110 ppb raw water
Bluegill LC_{50} = 130 ppb in pond water
Gammarus faciatus LC_{50} = 0.8 ppb

Chronic Exposure: 1/4 acre ponds containing bluegill and catfish and were used to measure chronic effects when applications reached 0.002 and 0.020 ppm. No clear indication of significant growth or hematocrit count differences were seen.

USFWS Sport Fisheries Research Report Publication 106, 1970 Wash. DC.

Reported Results of Acute Testing: Rainbow trout LC_{50} = 93.5 ppb at 96 hours. Korean shrimp *Palaemon macrodactylus* LC_{50} = 33.7 ppb (21.3 - 53). Striped bass at 30 ppt. salinity , LC_{50} > 1000 ppb.

Effects of Insecticides on Feeding Activity of the Guppy, a Mosquito-eating Fish in Thailand - Rong, Suriyam, Y. et al, 1968. World Health Organization.

Results: 24 hour LC_{50} mosquito larvae = 50 ppb
24 hour LC_{50} Guppy = 50 ppb

Effects of Field Applied Rates of Five Organophosphorous Insecticides on Thermal Tolerance, Orientation and Survival of *Gambusia affinis*. Johnson, C.R. 1977.

Results: Ability to survive thermal change EC_{50} < 100 ppb. Mortality of 100% at 500 ppb malathion.

Effects of Mirex, Methoxychlor and Malathion on Development of Crabs. Bookhout, Cazlyn G. and John D. Costlow Jr., 1976, Duke University and Gulfbreeze Laboratory (USEPA) Pg. 53-69.

Methods: The study was designed to investigate effects to larvae development of crabs. Mudcrabs, *Rhithropanopeusn horrisii* and Blue crabs, *Callinectes sapidus* were studied.
Results-Malathion Exposure: Mudcrab larval survival was significantly reduced (100% to 12%) at 11 to 20 ppb, respectively. They did not survive past 2nd local stage at 50 ppb. Development time was also delayed between stages. Blue crab larvae development was slightly delayed but significant reduction in survival to megalopa stage was seen at concentrations of 50 ppb and less significantly reduced at 20 ppb. Total mortality in all stages was high in concentrations of 20 ppb or above compared to acetone controls.

Toxicity of Malathion to Mammals, Aquatic Organisms and Tissue Culture Cells.

Desi, I. et al, Division of Hygienic Biology, Budapest, Hungary, 1976

Methods: AChE was measured in rat brains. Adductor muscle activity was measured in the freshwater mussel *Anodonta cygnea.* Guppies were exposed to 100, 1000, 10,000, 1000 and 100,000 ppb of Malathion. 30 Daphnia were exposed to 100,000, 10,000, 1000,100, 10 and 1 ppb, in 300 ml of water (test repeated 3 times). Freshwater mussel larvae *Glochiduim*) shell closing activity was measured for 30 larvae over 3 min period after exposure to concentrations ranging between 100 and 100,000 ppb of malathion.
Results: Rats displayed inhibited levels of AChe and abnormal EEG's 90 days post exposure at concentrations of 75 and 38 mg/kg of body wt. *Anodonta cygnea* showed significantly reduced activity during 48 hour exposure at 10,000 ppb. No change noted at 1000 ppb or less. Guppies were killed at 1000 ppb or above. The LC_{50} for guppies was calculated to be 819 ppb. For Daphnia 100% mortality was observed at 10 ppb or above. No effects were observed at 1 ppb. Glochiduim were less active at 1 ppb but showed similar activity as the controls at 0.1 ppb (NOEL).

Malathion, Chronic Effects on Estuarine Fish - Holland, H.T. and Jack Lowe, Gulfbreeze Biological Laboratory, 1966.

Methods: Atlantic Spot, *Leiostomus xanthurus* were exposed to constant concentration of 10 ppb of Malathion for 26 weeks.
Results:Though brain AChE levels in treated fish were 70% of that in untreated fish, no other adverse effects on the spot were noted. After 1 week AChE levels returned to normal.

Microbial-Malathion Interaction in Artificial Saltmarsh Ecosystems. Bourquin, Al W. Gulfbreeze Laboratory, USEPA. 1975.

Methods: Natural bacteria samples from uncontaminated marsh were added along with 10 ml of sea water and 10 gm of sediment to 250 ml flasks. 10 mg. aliquots of malathion in acetone were added every 7 days. Cultures were analyzed for malathion levels and compared to control vial residue levels.
Results: Increased salinity sped up the degradation process. Malaoxon levels remained constant. Monocarboxylic acid and dicarboxylic acid levels increased. Conclusion was that chemical and microbiological processes will act to degrade the levels of parent malathion in saltmarsh environments

A Method for Establishing Acceptable Toxicant Limits for Fish - Malathion and Butoxyethanol Ester of 2, 4-D - Mount, Donald I. and Charles Stephan, 1967 U.S. Dept of Interior.

Methods: Fathead minnows exposed under flowthrough conditions for 9 months. Fish were 1" long fry. Four malathion test concentrations and a control were employed. Ten fish were initially tested pe tank with 2 tanks per concentration. Later this was reduced to 5 fish per tank to better stimulate spawning and decrease mating competition.

Results: Proposal was to divide the NOEC by the LC_{50} and use this fraction as a multiplication factor with other fish species LC_{50} levels to obtain acceptable LOC levels for other species groups. In this case of fathead minnow exposed to malathion the fraction was 1/45. 20% of the fish exposed to 580 ppb died after 7 weeks. However, survivors at this concentration were able to spawn and reproduce.

Determination of Malathion, Malaoxon, and Mono-and Dicarboxylic Acids of Malathion in Fish, Oyster, and Shrimp Tissue. Cook, Gary H. and James C. Moore, 1976. USEPA Gulfbreeze Laboratory.
Methods: Pinfish were exposed to 75 ppb for 24 hours
Results: Greatest tissue concentrations were the MCA and DCA metabolites. Malaoxon and parent malathion were not detected.

Toxicity of Malathion to Native Freshwater Mussels. Keller, Anne E. , 1995. National Biological Survey Laboratory, Gainesville, Florida.
Methods: A two year study was conducted with several species of endangered or threatened mussels in various lifestages (glocchidial, juvenile, and adult). Malathion was tested at concentrations as high as 500,000 ppb.
Results: Adults were not significantly effected at up to 350,000 ppb. LC50 values for glocchidia were determined to range from 133,000 to 494,000 ppb. Juvenile LC50 values ranged from 36,000 to 523,000 ppb.

Observations of Effects to Aquatic Organisms From Field Applications

Over its history Malathion has been used extensively over or near freshwater habitats and marshes for mosquito and medfly control. A number of aquatic field studies have been independently conducted and are still being conducted for this type of use pattern. A summarization of the studies contained in Agency files is provided below with a brief discussion of the reported results.

Dibrom/Malathion Formulation Use as a Piscicide (Hoff, James and Westman, James, 1965)
Methods: Various combinations tested to determine kill ratio for fish eradication efforts
Results: 3pt/2pt ratio of dibrom and malathion was found to be an effective combination for use as a piscicide.

Brain Acetylcholinesterase Inhibition in fish as a Diagnosis of Environmental Poisoning by Malathion (Coppage, D et al 1975) Gulfbreeze Environmental Research Lab.
Methods: Pinfish were wildcaught and acclimated for 3 weeks. A flowthrough exposure was conducted for 72 hours at up to 500 ppb of malathion dissolved in acetone.
Conclusions: Malaoxon is the active AChE Inhibitor they believe since the parent was not present 2 wks later. Inhibition of over 70% generally indicates impending death. This occurred at about 58 ppb. At 25 ppb AChE inhibition of about 34% observed , but with eventual recovery of the test fish.

Malathion Toxicity to Killifish in Delaware. Darsie, Richard and Coraiden, F. Eugene, 1958. Delaware Agricultural Research Station.

Methods: This study involved spraying of Delaware marsh near Odessa, Delaware. 381 fish (*Fundulus ocellaris)* were wildcaught and used in testing procedures. 25 fish were placed in each of several metal tubs containing 7 gallons of natural marshwater. An aerial spray was applied at 0.51 lb ai/acre of malathion mixed with 2 qts of diesel oil. Monitored rate was 167 droplets/inch^2.

Results: After 4 hours 26.3% of the fish died, 42.4% showed sublethal effects and 31.2% appeared unaffected. 26% of the sublethally effected fish died later even though placed in clean water while 74% recovered.

The study report also mentions field observation of extensive mortality to species of killifish during medfly spraying in Florida in 1958. (Applic.Rate was 0.2 - 0.75 lbs ai/A)

Effects of Malathion on Two Warmwater Fishes and Aquatic Invertebrates in Ponds. Kennedy, Harry D. and David Walsh. USFWS, Fish Pesticide Research Laboratory, Columbia, Mo., 1970.

Methods: Bluegills and Channel catfish were exposed. 4 applications were made at concentrations of 0.02 and 0.002 ppm over an 11 week summer period. Twelve ponds were treated. Pond surface areas were 688 m^2 with average depth of 0.76 m. and volume of 602 m^3.

Results: The 8-44% fish loss was not felt to be treatment related as controls also had similar losses. Treatment effects appeared to be reductions of aquatic insects particularly midges at high and low doses (0.02 ppm and 0.002 ppm). Mayflies were reduced also with a significant reduction occurring after the 3rd application.

Effect of Aerially Applied Malathion on Juvenile Brown and White Shrimp, *Penaeus aztecus* and *Penaeus setiferus*. Conte, Fred S. and Jack C. Parker - Texas A&M University 1975 (Am. Fisheries Society)

Methods: 3 Bayous and an estuarine lake were monitored. Mean water depth was 61 cm. Wild caught shrimp placed in cages were aerially sprayed at a rate of 85.7 g/hectare by aircraft at a speed of 145 km/hr. 7 to 3 passes were made at each site.

Results: In Test I within 9 hours after treatment 73% of all mortality occurred (24 of 50 shrimp died). Test II produced 50% mortality in 49 hours after application. Only 12% mortality occurred in Test III (estuarine lake). Water concentrations ranged from 2.0 to 3.2 ppb immediately after application.

Effects of Ground Application of Malathion on Saltmarsh Environments In Northwestern Florida. Tagatz, M.E., 1974. USEPA Gulfbreeze, Environmental Research Laboratory, Gulfbreeze, Florida.

Methods: Thermal fog and ULV application in Northwestern Florida were monitored. Malathion was applied during low tide with 2 week intervals between applications. Thermal fog was applied at 6

oz/Acre (Sept. & Oct 1972) to a saltmarsh pond with fuel oil carrier. Blue crabs, juvenile sheepshead minnow and adult grass shrimp were exposed.
Results-Thermal Fog: 1 application produced high mortality of shrimp after 7 days. Some reduced AChE levels were observed in fish. No mortality of fish or crabs occurred.

Methods: ULV application was made at 0.64 fl oz/Acre. Three applications were made by truck mounted aerosol generator, with a 330 foot swath. Grass shrimp, blue crabs, and sheepshead minnow were exposed in 18" diameter polyethylene tubs.
Results: No effects noted to animals. No treatment related mortality was observed. Residue levels were 0.28 - 0.34 ppb after the 3rd application.

Effects of Pesticides in Estuaries Along the Gulf and Southeast Atlantic Coasts.
Coppage, D.L. and T. W. Duke, 1971, USEPA, Gulfbreeze Laboratory
Methods: AChE inhibition measurements were made in spot, croaker and mullet in Louisiana after spraying malathion for mosquito control. Collected fish were frozen and shipped on ice to Gulfbreeze Normal levels were measured and reported to range from 1.08 to 1.45 before spraying commenced.
Results: After spraying AChE levels were reduced to as low as 0.09. Range of inhibition was measured at 97% to 11% inhibition. Inhibition in spot ranged from 97% to 11% inhibition. Inhibition spot lasted over 1 week (still 36% inhibition). Second spray was made 18 days after first and mullet were killed while spot and croaker suffered further reduction in AChE. Inhibition may remain over one month after spraying.

Mortality of Post larval and Juvenile Shrimp Caused by Exposure to Malathion -A Laboratory and Field Study. Proctor, Raphael R. Jr., Jane P. Corliss, and Donald Lightner, National Marine Fisheries Service, Galveston Laboratory, 1966.
Laboratory Methods: Postlarval white shrimp and brown shrimp were exposed for 48 hrs. in laboratory tanks.
Results: Calculated 50% lethality levels for adults were 25.5 to 21.3 ppb for post larval brown shrimp and 100% mortality of larvae was seen at concentrations as low as 18 ppb.

Field Methods: Caged shrimp were exposed in estuarine areas to application of malathion(95% ai) at 77.8 ml/acre. Water depth was about 1.2 meters (high-tide) for the first application and 0.3 meters at the time of the second application (mean tide).
Field Monitoring Results: Environmental concentrations reached 8.9 ppb at high tide and 69 ppb at mean tide level. Some contamination of control areas occurred possibly from drift. 14% mortality wa observed in controls and 80% mortality was seen in the test marsh. In the second application 65-69 ppb residue levels were seen 6 hours after treatment. Mortality was 48% in treated area and 4% in control area. After 10 hours white shrimp mortality increased to 96% in treated area and 7% in contro area at mid depth levels. By 24 hours the residue levels had decreased to 1.08 ppb. White shrimp caged on the bottom level showed a similar trend after second application. Brown shrimp mortality results were inconclusive as treated areas showed 55% mortality while controls showed 44% mortality

Impact on Fish and Wildlife From Broadscale Aerial Malathion Applications in South San Francisco Bay Region, 1981. Finlayson, B.J., G. Faggella, H. Jong, E. Littrell, and T.Lew, Pesticide Investigation Unit, Water Pollution Control Laboratory, California Fish and Game Department.

Methods: This 120 page report summarizes extensive monitoring performed during 1981 Medfly control programs around the San Francisco Bay region. In general, most of the 200 fish and invertebrate tissue samples taken contained no detectable levels of malathion residues (<0.5 ppm). Thi was not true in the case of samples taken at fish kill sites. Steelhead trout populations were monitored in the San Lorenzo drainage area. Aquatic insect populations in the drainage were also monitored (number per sq. Cm).
Results: No discernable effects were noted for steelhead trout populations or appearance or size measurements when compared to control sites. There were significant reductions in either diversity o population counts for aquatic insects (33-50% reduction). Eight fish kills were associated with malathion spraying efforts, while 15 were either not determined as to cause or not attributed to malathion (see incident report section of this document). Many of the fish losses were sticklebacks (highly sensitive to malathion) while carp and channel catfish appeared unaffected at the same location

Impact of Malathion on Fish and Aquatic Invertebrate Communities and on Acetylcholinesterase Activity in Fishes in Stewart Creek, Fayette County, Alabama. Kuhajda, B.R. et al, Dept. Of Biological Sciences, University of Alabama, 1996.
Methods: Creek is located in west-central Alabama near Winfield and has an approximately 11 square mile drainage basin. Samples were taken upstream, at the entry point, and 0.5 mi. downstream from the application site on two small cotton fields (7.6 and 11.6 acres). Fields were within 25 feet of the stream bank. There were no trees along the banks, only grasses and kudzu vines. Sample sites were sampled for three years-the first two during malathion applications, the last during which malathion wa not applied. Captured fish were identified, counted , and some analyzed for AChE inhibition. Invertebrates were captured (by kicking up sediments into a dipnet), recorded, and then preserved in ethanol. 39 samples from each location were taken over a 34 month period. Only one sample date represented prespray conditions.
Results: Concentrations recorded ranged from ND to 10.89 ppb (mean=3.49 ppb) for the nine 1993 applications and from 0.88 to 31.1 ppb (mean=2.08) during the four 1994 applications.. 11,921 fish o 48 different species were collected during the study. Numbers and diversity of collected fish did not appear to significantly vary. Not all species were equally distributed at the three sites and some population differences may be attributable to the differences in habitat preferences and availability at tl three sites. Numerous specimens of rough shiner, *Notropis baileyi* were collected and analyzed for AChE and significant depression was noted during the spray periods when compared to the upstream control site. Of interest is the observation that downstream activity levels were lower than those at the application site.

Aquatic invertebrate populations which were collected included 87 taxa, and a total of 6,088 individual organisms. Some difference is apparent in numbers and diversity of species collected near the spray site when compared to the upstream site, but significant differences were less apparent at the downstream location. The upstream location did have more taxa present, however, than either of the other two sites for all periods of this study. The study author was not certain that this could be attributable to malathion influence as natural variability could also have played some part.

Freshwater, Estuarine and Marine Aquatic Incidents:

The Agency receives and reviews all wildlife incidents where aquatic organism kills occurred following application of a pesticide or mixture of pesticides. These incidents are sometimes reported under 6a2 provisions of FIFRA while others are independently submitted by local, state, or federal agencies. Those which areassociated with malathion use in the area of the kills are summarized below along with factors which are known about events preceding the incident.

Table 27. Freshwater, Estuarine and Marine Aquatic Incidents.

Location and Date	Incident #	Description	Probability
Florida Medfly report-1997 Spray operations Hillsborough Area USDA Report	6 reports from 7/29-8/28	40 Sites of Fish kills investigated-malathion detected in varying amounts in ponds and pools. Fish species effected include-various sunfish, bass, perch, and carp. 3 tropical fish farms hit. Mortality ranged from 5 to 1000 fish per site. Aerial drift generally blamed though some runoff events did occur.	Probable-residues detected in water and sometimes tissues
South Dakota, Minihaha Co., 7/6/87	I000804-025	10,000 dead fish-incl. walleye and yellow perch-aerial-Clean Crop -near Lake Madison	Probable
North Carolina, Wake Co., 5/17/73	B0000-225	10,000 panfish killed from ½ gallon spill of formulation(12.2 % Malathion/12.2% endosulfan into a pond.	Highly probable
Mississippi, Silver Creek, 7/6/89	I000389-001	166 fish, mostly carp, were killed-pest control company applied Aqua Malathion 8 in area	Possible
Missouri, 5/5/70	I000636-002	33 fish kill reports-one sick dog from ingestion of contaminated water	Possible
South Dakota, 7/3/87	I000804-025	35 other incidents besides Lake Madison fish kill-birds, fish, bees effected	Possible
Alabama	I002059-002	2 fish kills-Cotton field application of malathion-bass and sunfish killed	Possible
Florida	I000524-008	Turtle and birds mortalities reported	Possible

New Jersey, Delaware River 8/9/91	none-	Malathion distributed in sewage effluent to kill flies-15 gal malathion product /13000 gal effluent-1000 to 5000 white perch killed at discharge point	Probable
Maryland, Cherry Hill-5/12/80	EPA report	350 fish found dead- 10,000 acre lake-municipal pest control - Malathion	Probable
Missouri, Wentzville.-6/29/80	EPA report	6,790 dead fish counted-Malathion treated municipal sewage discharge to McCoy Creek	Probable
South Carolina, Hilton Head-5/25/81	EPA report	1500 dead fish-Sea Pine Lagoons-estuary-pesticide spraying operations using Malathion	Probable
Virginia, Norfolk-8/14/81	EPA report	1500 dead fish-Mason Creek-industrial operations using Malathion	Possible
Florida, near Miami - Summer, 1956	Old report from Mr. J.E. McCurdy-Florida Mosquito Control?	Extensive observations of numerous canals, ponds, ditches, and pools after aerial application of Malathion-some species killed others not-mortality to thousands of mojarra silversides was immediate after spraying-snook, mollies, cyprinids, pinfish , bass and killifish also killed in ditch and canal areas-strangely gambusis were not sensitive	Probable
Massachusetts-four incidents White Island Pond near Plymouth Glen Charles Pond near Waneham Waneham River-estuary Agawan River-estuary	6a2 Report from American Cyanamid Oct. 4, 1990 #281720	4 fish kills reported from treatment of 700,000 acres of estuarine areas with Malathion for control of mosquitoes. Many of the dead fish were estuarine killifish species.	Probable
New York, Thornwood-5/14/84	EPA report	500 dead fish-Pond in Carroll park-agriculture operations using malathion adjacent to pond	Possible
California-Monitored aquatic incidents during broadscale aerial application over San Francisco, Bay area ,1981. Administrative Report 82-2, Dept. Of Fish and Game, Environmental Services Branch, 1982.	Medfly Control	23 fish poisoning incidents were investigated-8 were confirmed as caused by malathion -10 were listed as undetermined causes-2 were caused by chlorine discharge at sewer plants. Malathion incidents included observed mortality of over 2300 fish including stickleback(Stevens, San Tomas Aquino, Pescadero Creeks), carp(Adobe and Mission Creeks), mosquitofish(Mission Creek), topsmelt, flounder, striped bass, and gobies(Seal and Redwood Creek, and Mayfileld Sloughs), and largemouth bass and crappie in San Jose Pond.	Probable-Malathion residues detected in water-tissue concentrations in gill filaments, liver, skeletal muscle and whole body tissues

Alabama, Tennessee 1995 Southeast Bollweevil Eradication Program, Environmental Monitoring Report	USDA /APHIS 1995 report	Leighton, Alabama-Catfish Farm-dead catfish-600 ft from aerially treated field(#295) Lincoln Co., TN.-2 acre stream fed pond-4 cotton fields upstream-dead bass, catfish, sunfish. Lighten, AL.-Big Nance Creek-30,000-40,000 fish Colbert Co.,AL.-Donnegan's Slough-fish kill-both followed heavy rains 8/4-8/8 resulting from hurricane Fish pond near Site 139-dead sunfish, catfish-malathion residues in water-5 to 6 ppb Catfish Farm-2 ponds-dead catfish near field #19-150 feet from ponds-9 old day samples did not show high concentration levels-only trace levels Fishkill-1/10 acre pond near field #303-dead adult catfish sampled-malathion detected in water. Fish, turtle, frog, and crayfish kill-5 acre wetland-2 to 3 ft. Depth-cotton field 503 located 600 ft. away-drainage ditch leads to wetland-6 day old samples-malathion still detected in water and fish tissues. Fish Kill(bass, sunfish, catfish)-8 acre pond-20 ft. From application site(cotton field # 1180)-residues of 77.8 ppb in one water sample. Other chemicals used in area-Larvin and Pyrat Fishkill -1/4 acre farm pond near cotton fields #118 and 119-malathion residues in all 4 water samples-fish tissue sample contained 351ppb malathion. Fishkill(catfish)-1/4 acre pond near field#166-70 ft from pond-malathion detected in 8 day post-application samples-	Probable-inspection was too late in many cases-1 week after Possible-Endosulfan, malathion and methyl parathion all suspect. Probable- Probable Possible Probable-fish tissue residues 35-85 ppb. Probable-though not likely from bollweevil aerial treatment, 6 weeks previous Probable-residue levels in tissues were high Possible-sampling too late-cotton field treated 8 days earlier
California-4 Incidents near Fremont, Loma Mar, San Jose, and San Mateo Co. 9/30/81-10/9/81	EPA report	2000 dead fish-Fremont Creek-crop treatment 200 dead fish-Pescadero Creek-crop treatment 75 dead fish-pond near San Jose-crop treated 12 dead fish-Adobe creek-crop treatment	Possible

Significance of Reported Incidents

Though malathion has been used for many years, the greatest numbers of detailed reports of fish kill incidents involved heavily monitored programs such as USDA's boll weevil eradication program and the mediterranean fruit fly eradication efforts. Other incidents appeared linked to uses near aquatic habitats where direct drift may have occurred, such as mosquito control. In many of the incidents use rates and residue levels following the incidents are not clear and kills are investigated days after the event probably occurred. In two of the incidents sewage discharge was treated with malathion to control flies and then released directly into tributaries. In all cases where residue levels are provided they are within the limits expected to prove toxic to sensitive fish species (>4 ppb). One of the points that should be included when discussing fish kill incidents is that invertebrates are likely to have been more severely effected since fish are less sensitive to malathion than a majority of the invertebrate species tested in laboratories to date. In most of the fish kill incidents there appears to have been no effort to investigate the effects to the other components of the ecological community in the adversely effected sites.

Toxicity to Plants

To date the Agency has received no data from malathion registrants regarding the toxicity of malathion to non-target plants. This is not normally a requirement for insecticidal use pesticides. However, the direct application of malathion to aquatic habitats does raise concerns regarding possible phytotoxicity of the product impurities or inert ingredients to non-target aquatic plants or semiaquatic plants. Based on the following study and also results observed in field studies (see previous study, MRID 00104629 Giles, 1970) malathion is expected to be taken up and stored for some time in plant tissues. Metabolites may later show up in new stem and leaf growth.

Comparative Metabolism of Malathion - C_{14} in Plants and Animals. Bourke, J.B. et al New York State Agricultural Experiment Station, Cornell University, 1968.
<u>Methods:</u> Red Kidney bean plants were forced to imbibe radio labeled malathion solution by passing air over foliage for 20-30 minutes (with solution mixed into air stream?) C^{14} was traced in tissues of plants for 14 days. Various intermediates (metabolites) were deposited within tissues.
<u>Results:</u> Plants appeared to store various metabolites in tissues..

Toxicity of Degradates and Impurities

Malathion may contain impurities which account for up to 5% of the pesticide content. These impuriti include diethyl fumarate, diethylhydroxysuccinate, O,O-dimethylphosphorothioate, O,O,O-trimethyl phosphorothioate, O,O,S-trimethyl phophorodithioate, ethyl nitrite, diethyl-bis (ethoxycarbonyl)mercaptosuccinate, S-1, 2-ethyl-O,S-dimethyl phosphorodithoate (isomalathion), S-(1-methoxycarbonyl-2-ethoxycarbonyl)ethyl-O, O-dimethyl phosphorodithoate, Bis-(O,O-dimethyl thionophosphoryl) sulfide, Diethyl methylthiosuccinate, S-ethyl-O,O-dimethyl phosphorodithioate, S-1,2-bis(ethoxycarbonylethyl-O,O,-dimethyl phosphorothioate (malaoxon), diethyl ethylthiosuccinate, and sulfuric acid. These impurities may range from 0.5% to 1.0 % of the content and have been shown to be toxic alone and may even potentiate the toxicity of the parent. Pellegrini and Santi, 1972, found that purified malathion (98% ai) was actually less toxic to laboratory rats than technical malathion of 92.2% purity with corresponding LD50 levels of 1580 mg ai/Kg versus 8000 mg ai/Kg, respectively.

Several studies regarding the toxicity and retention of degradates in fish were reviewed from literature. In 1976 studies at the EPA Gulfbreeze Laboratory, Cook and Moore found that the monocarboxylic and dicarboxylic acids of malathion were detected in fish tissues after 24 hours, but malaoxon and malathion were not. Studies by Dr. Michael Bender at the University of Michigan (1969) and Virginia Institute of Marine Sciences (1976) showed that diethyl fumarate and 2 mercapto diethyl succinate were more toxic than the parent compound to fathead minnow and eastern mudminnows (see pages 71-72). However the percentage of these degradates in the environment is expected to be low enough(<10% of original parent) to prevent additional toxicity to fish. Unfortunately, the testing reported for degradate toxicity was not performed on fish species considered highly sensitive to malathion (fathead minnow and eastern mudminnow). No degradate toxicity to invertebrate species has been reviewed. Toxicity from acculmulation of degradates following multiple applications is uncle without further fate and chemistry data to characterize their potential to degrade in the environment.

Toxicity of Dual Active Mixtures

Mixture Toxicity to Terrestrial Wildlife

Malathion and Methoxychlor mixtures are manufactured by Cheminova and Platte Chemical Company. Only Platte Chemical Co. markets this product in the U.S. There is some data regarding the possibility of increased toxicity of combinations of pesticides to rats and mice(M.L. Keplinger and Deichmann, 1967). In their paper entitled Acute Toxicity of Combinations of Pesticides (Toxicology and Applied Pharmacology 10, 586-595(1967), Keplinger and Deichman tested numerous mixtures of pesticides commonly used at the time. Rats and mice were orally intubated with pesticides mixed in corn oil. Generally 5-7 dosages were administered to five animals at each level, with separate chemicals administered within 10 seconds of each other. When methoxychlor was mixed with malathion there was a slight additive effect to expected toxicity, based on the author’s computation, which assumed that the expected LD50 of the combined chemicals would be equivalent to the midpoint between the known oral toxicities of the two compounds alone. The expected LD50 of methoxychlor/malathion 50 50 mix was estimated to be 1850 mg/Kg for mice whereas the actual observed LD50 was 1620 mg/Kg. This may be an inadequate difference on which to base any gross assumptions of synergistic effect for these two chemicals in combination. However, it should be noted that certain other combinations of malathion did show additive effects (toxaphene and carbaryl) whereas a protective effect was noted with certain other combinations (aldrin, dieldrin, chlordane, and endrin) when the sam assumptions for predicted LD50 levels were made.

Malathion is formulated with several other active ingredients which also may display some levels of toxicity to birds. Among these is Fertilome A-C-G Insecticide and Fungicide Mix marketed by Voluntary Purchasing Group Inc., Blackleaf Liquid Fruit Tree Spray with Fungicide (Sureco Inc.).

These formulations may have additional toxicity over single active formulations containing only malatl and should be tested separately. At this time the Agency has no data on which to predict potential effects to birds from aggregate exposure to these multi-active formulations. Comparison of methoxychlor and malathion avian toxicity values (see table below) indicates that methoxychlor displa low acute values similar to malathion . The mixture of these compounds may provide some additional exposure time due the increased persistence of methoxychlor over malathion. The reviewer was unabl to locate data to indicate that the mixture will or will not be more toxic due to synergistic effects of th two insecticides. The fungicide/insecticide mixtures may also add additional toxicity to avian species. This is based on slightly elevated plasma butyryl cholinesterase (BChE) levels in quail when malathion was administered in combination with vinclozolin and ketoconazole and elevated BChE levels in rats when malathion was administered in combination with propiconazole, vinclozolin, and clomitrimazole (Martin, J.J.R. and Thomas Badger, University of Arkansas, Toxicology and Pharmacology 130, 221-228,1995). In studies with Japanese quail, red-legged partridge, and pigeons pretreatment with the fungicide prochloraz resulted in enhanced toxicity of malathion (Riviere J.L. et al, Arch. Environmenta Toxicology 14, 1985 and Johnston, G. et al., 1989 Pesticide Biochem. Physiology 35, 107-118)

Table 28. Comparative Toxicity of Malathion and Methoxychlor to birds.

Species	% ai	Malathion	% ai	Methoxychlor
Mallard	95%	LD50=1485 mg/Kg	Tech	LD50=2000 mg/Kg
Ring-necked Pheasant	95%	LC50=2639 ppm	Tech	LC50>5000 ppm
Bobwhite	95%	LC50=3497 ppm	Tech	LC50>5000 ppm

Mixtures containing malathion and methoxychlor may produce similar or more pronounced chronic effects if additional persistence results from addition of the organochlorine insecticide.

Mixture Toxicity to Aquatic Organisms

Studies published by the Bureau of Sport Fisheries and Wildlife(later USFWS) in the June 1970 issue of Progress in Sport Fishery Research 1969, explored the synergistic activity of combinations of pesticides on toxicity levels for bluegill and rainbow trout. Synergism was observed when malathion was mixed with baytex, EPN, Parathion, Perthane, and Carbaryl. Additive effect was noted when combined with DDT and Toxaphene.

Review of toxicity data for methoxychlor indicates that this chemical may provide additional toxicity over that of malathion to most species of aquatic organisms. A brief , but not comprehensive, comparison table is presented below for comparison of acute toxicity values for the two insecticides t fish and invertebrates. The Agency has not received data to support the registration of methoxychlor/malathion mixtures.

Table 29. Malathion / methoxychlor comparative toxicities to aquatic organisms

Species	%ai	Malathion	%ai	Methoxychlor
Waterflea, *Daphnia pulex*	95	EC50=1.8 ppb	98	EC50=0.78 ppb
Scud, *Gammarus fasciatus*	95	EC50=0.5 ppb	98	EC50=1.9 ppb
Scud, *Gammarus lacustris*	95	EC50=1.8 ppb	98	EC50=0.8 ppb
FW shrimp, *Palaemontes kadiakensis*	95	LC50=12 ppb	98	LC50=1.05 ppb
Waterflea , *Simocephalus serrulatus*	95	EC50=0.59 ppb	98	EC50=5.0 ppb
Seed shrimp ,*Cypidopsis vidua*	95	LC50=47 ppb	98	LC50=32 ppb
Blue crab, *Callinectes sapidus*	95	LC50>1000 ppb	100	LC50=320 ppb
Oyster, *Crassostrea virginica*	95	EC50>1000 ppb	100	LC50=90 ppb
Sowbug, *Asellus brevicaudus*	95	LC50=3000 ppb	98	LC50=34 ppb
Cutthroat trout, *Oncorhynchus clarki*	95	LC50=1740 ppb	98	LC50=6.2 ppb
Yellow perch, *Perca flavens*	95	LC50=263 ppb	98	LC50=17.5 ppb
Channel catfish, *Ictalurus punctatus*	95	LC50=7620 ppb	98	LC50=52 ppb
Bluegill sunfish, *Lepomis macrochirus*	95	LC50=20 ppb	98	LC50=32 ppb
Rainbow trout, *Oncorhynchus mykiss*	95	LC50=4 ppb	98	LC50=11 ppb
Spot, *Leiostomus xanthurus*	95	LC50=320 ppb	100	LC50=23 ppb

Based on the data reviewed thus far for the two chemicals it would appear that the mixture may prove more toxic to most species of aquatic organisms if based on an equivalent active ingredient % of malathion alone. There will, however, be species sensitivity differences in some instances.

Ecological Risk Assessment

Exposure and Risk to Nontarget Terrestrial Wildlife

The acute risk quotients for broadcast applications of nongranular products are tabulated below. They are based on estimated acute and chronic residue levels calculated in the terrestrial exposure portion o this document divided by the LC50 or chronic NOEC of the most sensitive species tested.

1. Birds

Avian Acute and Chronic Risk Quotients for Single Application of Nongranular Products (Broadcast or Foliar Spray) are based on the most sensitive species ringneck pheasant LC50 of 2639 ppm and the chronic NOEC for bobwhite quail of 110 ppm.

Multiple application scenarios were estimated using a first order dissipation program incorporating Fletcher values in conjunction with the appropriate half-life values. The worst case scenario for each application rate is reflected in the table, that is the minimum interval and maximum number of applications permitted under tolerance testing for this crop group. A mean foliar dissipation half-life 5.5 days was inputed into the program, based on monitored values from several studies including USDA bollweevil and medfly programs and research efforts by Willis and McDowell, 1987 (referenced in previous terrestrial exposure section). Samples of the actual outputs are included as addendums to this document.

The risk quotient results indicate that for a single broadcast application of nongranular products, avian acute high (0.5), restricted use (0.2), and endangered species (0.1) levels of concern are exceeded at registered multiple application rates equal to or above 3.75 lb ai/A , 2.0 lb ai/A and 0.94 lb ai/A , respectively.

Table 30 **Avian Acute Dietary Risk Quotient Ranges**

Cheminova and IR4 Supported Maximum Tolerance Rates and Scenarios on Grasses-Seed

	Foliar Dissipation T1/2=5.5 Days						**Number of Applications**							
	Rate	**Int Day**	**1 grass-seed**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12-25**
A	**0.175**	7D	0.01-0.0004									0.02-0.001	
B	**0.50**	NA	0.04-0.001										
C	**0.61**	5D	0.05-0.001				0.11-0.007						
C	**0.61**	7D	0.05-0.001	0.07-0.003	0.09-0.005								
C	**0.61**	14 D	0.05-0.001	0.06-0.004									
D	**0.76**	10 D	0.06-0.002				0.09-0.006						
E	**0.94**	3D	0.08-0.002										
E	**0.94**	6D	0.08-0.002					0.15-0.01					
E	**0.94**	7D	0.08-0.002		0.13-0.008				0.15-0.009				
F	**1.0**	7D	0.09-0.002					0.15-0.009					

G	**1.25**	3D	0.1-0.003	0.19-0.01				0.32-0.02					
G	**1.25**	5D	0.1-0.003				0.23-0.014						
G	**1.25**	7D	0.1-0.003		0.17-0.01	0.19-0.01	0.19-0.01	0.19-0.01	0.19-0.01	0.19-0.01	0.19-0.01	0.19-0.01	0.19-0.01
G	**1.25**	14 D	0.1-0.003	0.13-0.008									
H	**1.50**	7D	0.13-0.003		0.21-0.01			0.23-0.01					
I	**1.56**	7D	0.14-0.004	0.16-0.006			0.23-0.01						
J	**1.88**	5D	0.17-0.004					0.36-0.02					
J	**1.88**	7D	0.17-0.004		0.27-0.02	0.28-0.02		0.29-0.02					
J	**1.88**	14 D	0.17-0.004	0.2-0.01									
K	**2.03**	6D	0.18-0.005					0.34-0.02					
K	**2.03**	7D	0.18-0.005		0.29-0.02	0.30-0.02							
L	**2.5**	3D	0.22-0.006		0.5-0.02								0.7-0.04

Avian Acute Dietary Risk Quotients **(continued)**

L	**2.5**	5D	0.22-0.006		0.42-0.03								
L	**2.5**	7D	0.22-0.006		0.36-0.02		0.38-0.02						
M	**3.43**	5D	0.31-0.009				0.42-0.02						
N	**3.75**	7D	0.34-0.01			0.56-0.02		0.58-0.04					
N	**3.75**	14 D	0.34-0.01										
O	**4.7**	30 D	0.42-0.01	0.43-0.01									
P	**5.0**	7D	0.45-0.01	0.64-0.01	0.72-0.3	0.75-0.03							
Q	**6.25**	30 D	0.57-0.02		0.58-0.01								

0.175 lbai/A **A10**=Orange, Grapefruit, Lemon, Lime, Tangerine, Tangelo, and Kumquat
0.50 lb ai/A **B1**=Flax

0.61 lb ai/A	**C5(5D)**=Sweet Corn **,** **C2(7D)**=Hops, **C3(7D)**=Beans, Corn, Rice, Sorghum, Wheat, and Rye **C2(14D)**=Alfalfa, Clover, Lespedeza, Lupine and Vetch
0.76 lb ai/A	**D5**=Blueberry
0.94 lb ai/A	**E1(3D)**=Grass for hay, **E4(3D)**=Mushroom, **E6(6D)**=Strawberry, **E3(7D)** =Peppermint and spearmint, **E7(7D)**=Macadamia
1.0 lb ai/A	**F6(7D)**=Melons, Watermelon, Pumpkin and Winter Squash
1.25 lb ai/A	**G1(3D)**=Grass for hay, **G2(3D)=**Field corn **, G2(7D)** Brussel sprouts, cauliflower, collards, kale, kohlrabi **G6(3D)**=Mustards**,** **G25(3D)=**Cotton, **G5(5D)=**Watercress, **G3(7D)**=Rice, Sorghum, Wheat, Rye, Barley, Oats and Corn, **G4(7D)**=Blueberry(ULV), **G5(7D)**=Turnip, Broccoli, Apple, Sweet Corn, Beet, Horseradish, Parsnip, Radish, Rutabaga, Salsify, **G6(7D)**= Cabbage and Cherry(ULV), **G7(7D)=**Carrot , **G8(7D)**=Mango and Passion fruit **, G9(7D)**=Asparagus **G10(7D)**=Pears and Quince , **G12(7D)**=Guava and Papaya, **G2(14D)**=Alfalfa, Clover, Lupine, Vetch and Lespedenza
1.5 lbs ai/A	**H2(7D)**=Celery, **H6(7D)**=Okra
1.56lbs ai/A	**I2(7D)**=Potato, Sweet potato, **I5(7D)**=Onion, Garlic, Shallot, Leeks
1.88 lb ai/A	**J6(5D)**=Lettuce, **J4(7D)**=Blackberry, Raspberry, Loganberry, Boysenberry, Dewberry, Currant, Gooseberry, **J3(7D)**=Cucumber, Chayote, **J6(7D)**= Strawberry, **J2(14D)**=Grapes
2.03 lbs ai/A	**K6(6D)**=Strawberry(50%WP), **K3(7D)**= Spinach, Dandelion, Endive, Parsley and Swiss Chard, **K4(7D)**=Blackberry, Raspberry, Gooseberry, Loganberry, Dewberry, Currant and Boysenberry
2.50 lb ai/A	**L25(3D)**=Cotton, **L3(5D)**=Figs, **L3(7D)**=Mustards, Walnuts, and Pecans, **L5(7D)**=Peas
3.43 lb ai/A	**M5(5D)**=Tomato, Pepper, Eggplant
3.75 lb ai/A	**N4(7D)**=Apricots, **N6(7D)**=Cherry, **N4(14D)**=Peach and Nectarine
4.7 lb ai/A	**O2(30D)**=Avocado
5.0 lb ai/A	**P3(7D)**=Pineapple**,** **P4(7D)=**Chestnuts
6.25 lb ai/A	**Q3(30D)**=Oranges, Grapefruit, Lemon, Lime, Tangerine and Tangelo

Chronic risk quotients can be calculated based on the average residues on food items. Average residues result from the pesticide being applied repeatedly, but degrading over the course of time from the first application to the last application. Due to rapid malathion degradation characteristics, high numbers of applications and minimal intervals in many cases, birds are expected to be exposed to continuous peaks at 3, 5, 6, 7, or 10 day intervals. Avian chronic risk quotients based on average residues for multiple, broadcast applications of non-granular products may not be as pertinent under this type of scenario, therefore maximum peaks were compared against the NOEC for bobwhite quail chronic test results. The results, depicted in the table which follows, indicate that for multiple broadcast applications of nongranular products based on expected peak residues, the avian chronic level of concern is exceeded at a registered maximum application rate equal to or above 0.5 lb ai/A on grasses (based on the assumption of chronic effects due to repeated exposure to peak residues with less than one week intervals). This chronic level could be maintained by continuous and repetitive applications during a crop season.

Table 31. Avian Chronic Risk Quotient Ranges

Cheminova and IR4 Supported Maximum Tolerance Rates and Scenarios on Grasses-Seeds

	Foliar Dissipation T1/2=5.5 Days		**Number of Applications**										
	Rate lb ai/A	**Int. Day**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12-25**
A	**0.175**	**7D**	0.4-0.01									0.7-0.04	
B	**0.50**	**NA**	1.09-0.03										
C	**0.61**	**5D**	1.3-0.03				2.7-0.17						

C	**0.61**	**7D**	1.3-0.03	1.7-0.08	2.1-0.12									
C	**0.61**	**14D**	1.3-0.03	1.6-0.1										
D	**0.76**	**10D**	1.7-0.05				2.3-0.14							
E	**0.94**	**3D**	2.0-0.06											
E	**0.94**	**6D**	2.0-0.06					3.8-0.05						
E	**0.94**	**7D**	2.0-0.06		3.2-0.2				3.5-0.2					
F	**1.0**	**7D**	2.18-0.06					3.7-0.22						
G	**1.25**	**3D**	2.72-0.08	4.6-0.3				7.8-0.5						
G	**1.25**	**5D**	2.72-0.08				614-38							
G	**1.25**	**7D**	2.72-0.08		4.3-0.3	4.4-0.3	4.6-0.3	4.6-0.3	4.6-0.3	4.6-0.3	4.6-0.3	4.6-0.3	4.6-0.3	
G	**1.25**	**14D**	2.72-0.08	3.2-0.2										
H	**1.50**	**7D**	3.3-0.09		5.2-0.33			5.5-0.34						
I	**1.56**	**7D**	3.4-0.1	3.9-0.14			5.7-0.35							
J	**1.88**	**5D**	4.1-0.11					8.6-0.5						
J	**1.88**	**7D**	4.1-0.1		6.5-0.4	6.8-0.4		7.0-0.4						
J	**1.88-**	**14D**	4.1-0.1	4.8-0.3										
K	**2.03**	**6D**	4.4-0.1					8.2-0.5						
K	**2.03**	**7D**	4.4-0.1		7.0-0.4	7.3-0.45								
L	**2.5**	**3D**	5.45-0.2		11.7-0.5								17.3-1.1	
	Rate lb ai/A	**Int**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12-25**	
L	**2.5**	**5D**	5.45-0.2		10.1-0.6									
L	**2.5**	**7D**	5.45-0.2		8.6-0.5		9.1-0.6							
M	**3.43**	**5D**	7.6-0.2				9.2-0.6							
N	**3.75**	**7D**	8.1-0.24			13.5-0.6		13.9-0.9						
N	**3.75**	**14D**	8.1-0.24											

O	**4.7**	**30D**	10.2-0.3	10.4-0.3									
P	**5.0**	**7D**	10.9-0.3	15.4-0.4	17.3-0.6	18.1-0.7							
Q	**6.25**	**Q1**	13.6-0.4		14.0-0.4								

0.175 lbai/A **A10**=Orange, Grapefruit, Lemon, Lime, Tangerine, Tangelo, and Kumquat
0.50 lb ai/A **B1**=Flax
0.61 lb ai/A **C5(5D**)=Sweet Corn **,** **C2(7D**)=Hops, **C3(7D**)=Beans, Corn, Rice, Sorghum, Wheat, and Rye~~,~~
C2(14D)=Alfalfa, Clover, Lespedeza, Lupine and Vetch
0.76 lb ai/A **D5**=Blueberry
0.94 lb ai/A **E1(3D**)=Grass for hay, **E4(3D)**=Mushroom, **E6(6D)**=Strawberry, **E3(7D)** =Peppermint and spearmint,
E7(7D)=Macadamia
1.0 lb ai/A **F6(7D)**=Melons, Watermelon, Pumpkin and Winter Squash
1.25 lb ai/A **G1(3D)**=Grass for hay, **G2(3D)=**Field corn **, G2(7D)** Brussel sprouts, cauliflower, collards, kale, kohlrabi
G6(3D)=Mustards**,** **G25(3D)=**Cotton, **G5(5D)=**Watercress, **G3(7D**)=Rice, Sorghum, Wheat, Rye, Barley, Oats and Corn, **G4(7D)**=Blueberry(ULV), **G5(7D)**=Turnip, Broccoli, Apple, Sweet Corn, Beet, Horseradish, Parsnip, Radish, Rutabaga, Salsify,~~Sweet potato,~~ **G6(7D)**= Cabbage and Cherry(ULV),
G7(7D)=Carrot , **G8(7D)**=Mango and Passion fruit **, G9(7D)**=Asparagus **G10(7D**)=Pears and Quince ,
G12(7D)=Guava and Papaya, **G2(14D)**=Alfalfa, Clover, Lupine, Vetch and Lespedenza
1.5 lbs ai/A **H2(7D**)=Celery, **H6(7D)**=Okra
1.56lbs ai/A **I2(7D)**=Potato, Sweet potato, **I5(7D**)=Onion, Garlic, Shallot, Leeks
1.88 lb ai/A **J6(5D)**=Lettuce, **J4(7D)**=Blackberry, Raspberry, Loganberry, Boysenberry, Dewberry, Currant, Gooseberry,
J3(7D)=Cucumber, Chayote, **J6(7D)**= Strawberry, **J2(14D)**=Grapes
2.03 lbs ai/A **K6(6D**)=Strawberry(50%WP), **K3(7D)**= Spinach, Dandelion, Endive, Parsley and Swiss Chard, -
K4(7D)=Blackberry, Raspberry, Gooseberry, Loganberry, Dewberry, Currant and Boysenberry
2.50 lb ai/A **L25(3D**)=Cotton, **L3(5D)**=Figs, **L3(7D**)=Mustards, Walnuts, and Pecans, **L5(7D)**=Peas
3.43 lb ai/A **M5(5D)**=Tomato, Pepper, Eggplant
3.75 lb ai/A **N4(7D)**=Apricots, **N6(7D)**=Cherry, **N4(14D**)=Peach and Nectarine
4.7 lb ai/A **O2(30D)**=Avocado
5.0 lb ai/A **P3(7D)**=Pineapple**,** **P4(7D)=**Chestnuts
6.25 lb ai/A **Q3(30D)**=Oranges, Grapefruit, Lemon, Lime, Tangerine and Tangelo

Mammals

Birds and mammals have similar responses to xenobiotics. Birds have lower hepatic microsomal mono oxygenase and A-esterase activity than do mammals. Therefore, birds are more susceptible than mammals to both organophosphate and carbamates in general. Malathion does not present an acute risk to mammals based on the low toxicity observed in exposure studies conducted with laboratory rats rabbits and mice.

However, malathion does present a potential for long-term dietary exposure to mammals if multiple applications are repeated with inadequate intervals to allow for complete degradation. Malathion does appear to offer potential chronic hazard to birds, but hazard to mammals appears to be less likely. In 2 year oncogenic studies with laboratory rats (Food and Drug Research Labs, 1980-ACC 248179-180) the animals were fed diets containing 0, 1000 and 5000 ppm of 92.1 % malathion. No gross adverse effects were noted, however decreased cholinesterase levels and body weight were noted at 1000 ppm test levels. In another study male and female rats were fed 4000 ppm of malathion in their diets (equivalent to 240 mg/kg/day) for five months. Reduced litter size and survival of young was observed in this study (Kalow and Marton, 1965). These effect levels are above those expected on vegetation from the highest rate scenario (1500 ppm on vegetation surrounding citrus at 6.25 lb ai/A). However, temporary reduction of acetocholinesterase levels is expected at higher rates of application.

Estimating the potential for adverse effects to wild mammals is based upon EEB's draft 1995 SOP of mammalian risk assessments and methods used by Hoerger and Kenaga (1972) as modified by Fletcher *et al.* (1994). The concentration of malathion in the diet that is expected to be acutely lethal t 50% of the test population (LC50) is determined by dividing the LD50 value (usually rat LD50) by the % (decimal of) body weight consumed. A risk quotient is then determined by dividing the EEC by the derived LC50 value. Risk quotients can then calculated for three separate weight classes of mammals (15, 35, and 1000 g), each presumed to consume four different kinds of food (grass, forage, insects, and seeds). The acute risk quotients for broadcast applications of nongranular products are tabulated using the equations below. The reviewer calculated quotients based on a full range of application scenarios, but not on every possible scenario. In addition larger mammals were not included as data suggests that toxicity thresholds will not be attained for the higher weight classes of mammals. As wit the risk quotient for birds, the driving influence on how high field residues (and thus the risk quotients) will be from multiple appears to be determined by the interval between applications more than the total number of applications of malathion. Chronic exposure to malathion is more a matter of continuous exposure to peak levels on a 3, 5, 6, 7, or 14 day cycles. Intervals of less than 7 days may allow buildup of malathion residues levels over time. Unfortunately, many of the mammalian chronic studie conducted for human health analysis are two year studies which are not truly comparable to a single season exposure period expected for wild mammals. In many of the chronic mammal studies less noticeable sublethal effects were noted such as reduced acetocholinesterase levels, in brain, blood and plasma((Hazelton Labs, AMA Arc. Occ. MED:8; 1953) or gastric ulcers(Nat. Cancer Institute, 1979). These types of effects would go unnoticed during field use in all probability.

Mammalian (Herbivore/Insectivore) Acute Risk Quotients for Single and Multiple Application of Nongranular Products (Broadcast) Based on rat LD50 of 390 mg/Kg

$$RQ = \frac{\text{EEC (ppm)}}{\text{LD50 (mg/kg)/ \% Body Weight Consumed}} \quad \text{or} \quad \frac{\text{EEC}}{\text{NOEC}}$$

Table 32. Worst Case RQ's for Dietary Consumption by Small Mammals:
Small Mammal-15 gram Wt consuming 95% of Food Matter as Shortgrass or Fruit
Small Mammal of 35 gm Wt consuming 66% of Food Matter as Shortgrass or Fruit

Site/App. Method	Rate (lbs ai/A)	Single Application Day 0 Max. EEC Range for Short grass to Fruits	Highest # Applic. (Minimum Interval)	Multi-App. Max. EEC Range-Shortgrass to Fruit	Acute RQ Range 15 g Body Wt Consuming 95%	Acute RQ Range 35 g BodyWt Consuming 66%
Citrus/Aerial	0.175	42 to 1.2 ppm	10X(7D)	43 to 2.7	0.10- 0.006	0.07 - 0.0045
Corn/Aerial	0.61	146 to 4.3 ppm	3X(7D)	195 to 12	0.47 - 0.029	0.33 - 0.02
Blueberry/Aerial	0.76	182 to 5 ppm	5X(10D)	195 to 12	0.47 - 0.029	0.33 - 0.02
Strawberry/Ground	0.94	226 to 7 ppm	6X(6D)	278 to 17	0.67 - 0.04	0.47 - 0.02
Melons/Ground	1.0	240 to 7.5 ppm	6X(7D)	280 to 17	0.68 - 0.04	0.48 - 0.02
Cotton/Aerial	1.25	300 to 8.8 ppm	25X(3D)	531 to 33	1.3 0 - 0.08	0.90 - 0.056
Onion/Ground	1.56	374 to 11 ppm	5X(7D)	437 to 27	1.06 - 0.07	0.74 - 0.046
Lettuce/Ground	1.88	451 to 13 ppm	6X(5D)	601 to 37	1.46 - 0.09	1.01 - 0.06
Strawberry/Ground	2.03	487 to 14 ppm	6X(7D)	526 to 33	1.3 - 0.08	0.90 - 0.056
Cotton/Aerial	2.50	600 to 18 ppm	25X(5D)	733 to 35	1.78 - 0.09	1.24 - 0.05
Tomato/Ground	3.43	823 to 24 ppm	5X(5D)	1096-68	2.67 - 0.16	1.86 - 0.11
Cherry/Ground	3.75	900 to 26 ppm	6X(7D)	1050-60	2.56 - 0.14	1.78 - 0.10
Avocado/Ground	4.7	1128 to 33 ppm	2X(30D)	1128-35	2.75 - 0.08	1.91 - 0.08
Pineapple/Ground	5.0	1200 to 35 ppm	4X(7D)	1400-40	3.41 - 0.09	2.37 - 0.068
Citrus/Ground	6.25	1500 to 44 ppm	2X(30D)	1500-44	3.65-0.074	2.54 - 0.07

Table 33.
Chronic RQ Ranges for Mammals - Exposure to Multiple/Continuous Residue Peaks
Based on Chronic Studies with Mice(MRID 242903) and rats (Document # 000389, Karlow and Marton, 1965)
Reduced Body Wt. -Mice At 500 PPM Reduced Pup Survival for Rats at 4000 ppm

Site/Method Application	Rate (lb ai/A)	# of Apps. (Interval)	Maximum EEC Range in PPM	Chronic RQ Growth	Chronic RQ Reproduction
Citrus/Aerial	0.175	10X(7D)	43 to 2.7	0.09-0.005	very low
Corn/Aerial	0.61	3X(7D)	195 to 12	0.39-0.024	very low
Blueberry/Aerial	0.76	5X(10D)	195 to 12	0.39-0.024	very low
Strawberry/Ground	0.94	6X(6D)	278 to 17	0.55-0.03	low
Melons/Ground	1.0	6X(7D)	280 to 17	0.56-0.03	very low
Cotton/Aerial	1.25	25X(3D)	531 to 33	1.06-0.07	0.13-0.008
Onion/Ground	1.56	5X(7D)	437 to 27	0.87-0.05	very low
Lettuce/Ground	1.88	6X(5D)	601 to 37	1.2-0.07	very low
Strawberry/Ground	2.03	6X(7D)	526 to 33	1.05-0.07	very low
Cotton/Aerial	2.50	25X(5D)	733 to 35	1.46-0.07	0.18-0.009
Tomato/Ground	3.43	5X(5D)	1096-68	2.19-0.13	0.27-0.017
Cherry/Ground	3.75	6X(7D)	1050-60	2.10-0.12	0.26-0.02
Avocado/Ground	4.7	2X(30D)	1128-35	2.26-0.07	0.28-0.008
Pineapple/Ground	5.0	4X(7D)	1400-40	2.80-0.08	0.35-0.01
Citrus/Ground	6.25	2X(30D)	1500-44	3.0-0.09	0.38-0.01

Malathion Used in Bait Applications

Though no granular malathion products are proposed for reregistration, malathion is used in a number of bait application uses. These liquid bait applications may be similar to granules in their route of ingestion by exposed wildlife. Mammalian species also may be exposed to bait droplets containing concentrated (95% ai) malathion. This would be applicable to such programs as the medfly eradicatior programs where malathion protease baits are employed to attract the target organisms (Mediterranean fruit fly). They also may be exposed by other routes, such as by walking on exposed bait and drinking water contaminated by malathion baits. The number of lethal doses (LD50's) that are available within one square foot immediately after application can be used as a risk quotient (LD50's/ft^2) for the variou types of exposure to bait pesticides. Risk quotients are calculated for a small mammal and for the ringneck pheasant.

Mammalian Acute Risk Quotients for Bait Products (Broadcast).

Use Site	Application Method	Rate in lbs ai/A	% Surface Residues
Medfly Control	Aerial	0.18	80% efficiency est.

Body Weight (g) Rat =100 gm Ringneck Pheasant=1135 gm
Based on a rat LD50 of 390 mg/Kg Ringneck LD50=167 mg/Kg

Mammalian Acute RQ[1] ($LD50/ft^2$)= 0.0000004

[1] $RQ = \frac{\text{Rate (lbs ai/A)} * (453{,}590 \text{ mg/lbs}/43{,}560 \text{ ft}^2/\text{A}) \times 80\%}{\text{LD50 mg/kg} * \text{Weight of Animal (g)} * 1000 \text{ g/kg}} = \frac{65316 \text{ mg}/43560}{390 \times 100 \times 1000} = \frac{1.5 \text{mg/sqft}}{3900000}$

Avian Acute Oral RQ (Pheasant)= $\frac{1.5 \text{ mg/sq ft}}{189545000} = 0.00000001$

The results above indicate that for aerial application of protease bait products at 0.18 lbs ai/A, no mammalian or avian acute levels of concern are exceeded. Currently, EFED has no procedure for assessing chronic risk to mammalian species for protein bait products.

Hazard to Non-Target Insects

Currently, EFED does not quantify risk to nontarget insects. Results of acceptable studies and actual field use observations are used for recommending appropriate label precautions. Acute toxicity to honeybees from acute contact or foliar contact with malathion residues is very high. Based on these acute studies and observations from field studies presented under the previous toxicity to insects secti of this document, acute hazard is expected for non-target pollinator insects (honeybees, etc) exposed t direct spray droplets, to residues on foliage, or to residues which are transported on pollen back to the hives or nests (Gary, N.E., 1984). This hazard can extend to pollinators with hives located several kilometers away from the application site, dependent on the distance range of flight paths associated with the particular species in question. Several field studies have shown increased mortality for colonies located as much as two kilometers away from application sites. Many other beneficial specie of insects and arachnids (lacewings,butterfly larvae and adults, spiders, beetles etc) are vunerable to non-crop spray applications which are used to control other pests of public concern such as medflies, mosquitoes, and flies (Dahlsten, D.L., 1983; Johansen,C.A., 1965). Spraydrift to aquatic habitats may produce adequate residue levels to prove hazardous to aquatic larvae of insects which later become important terrestrial members of the insect community (eg. dragonflies, mayflies, damselfiles, snipefl caddisflies, stoneflies etc.). Mortality to these types of larvae may occur at aquatic concentrations as low as 1 PPB. Studies by L.D. Jenson, 1965 showed that even after stonefly larvae were removed from exposure areas and placed in clean water mortality could still occur within 24 hours. Many of these larvae also serve as important food sources for juvenile fish.

Risk to Nontarget Freshwater or Estuarine Aquatic Organisms

Based on actual monitored concentrations, predicted modeling results, and actual fish kill incidents, there is acute hazard from contamination of aquatic habitats adjacent to or within target application areas. Tables presented below represent risk quotients for various application scenarios for agricultura and public health uses of malathion. Risk quotients which exceed 0.5 are considered to present acute hazard to the species in question. Risk quotients which exceed 0.1 are considered to offer potential hazard to endangered species within these groups (fish, crustacea, molluscs, amphibia, etc). The tables below present risk quotients for invertebrates and fish in the same table. The first number in each scenario cell pertains to the RQ associated with the acute EC50 (1 ppb) or chronic NOEC (0.1 ppb) associated with *Daphnia magna.* The second number in the cell represents the RQ for fish based on the LC50 of the bluegill sunfish (20 ppb) or the chronic NOEC for the rainbow trout early life stage te (4 ppb). The RQs are derived using predicted EECs from GENEEC (tables 35 and 36) or PRZM/EXAMS (table 37) and dividing them by the acute or chronic toxicity endpoints.

Table 34. Aquatic Organism Acute Risk Quotients-Invertebrate RQ/Fish RQ

Number of Applications -Cheminova and IR4 Supported Maximum Tolerance Rates and Crop Scenari													
	Rate	**Int**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12-25**
A	**0.175**	7D	**Inv/Fish**								**8.2/0.4**		
B	**0.50**	NA	**11.4/0.57**										
C	**0.61**	5D					*						
C	**0.61**	7D		**23.2/1.2**	**27.7/1.4**								
C	**0.61**	14D		**26.8/1.3**									
D	**0.76**	10D					**40.6/2.0**						
E	**0.94**	3D	**21.7/1.1**										
E		6D						**45.4/2.3**					
E		7D			**42.2/2.1**				**42.5/2.1**				
F	**1.0**	7D						**45.2/2.3**					
G	**1.25**	3D	**28.5/1.4**	**54.3/2.7**				**90.4/4.5**					**91.9/4.5**
G		5D					**66/3.3**						
G		7D			**56.1/2.8**	**56.5/2.8**	**56.5/2.8**	**57.2/2.9-A**	**56.5/2.8**	**56.6/2.8**	**56.6/2.8**	**56.6/2.8**	
G		14D		**47.1/2.4**									
H	**1.50**	7D			**67.3/3.4**			**67.3/3.4**					
I	**1.56**	7D		**7.8/3.4**			**70.8/3.5**						
J	**1.88**	5D						**99.4/5**					
J		7D			**84.4/4.2**	**84.9/4.2**		**85/4.2**					
J	**1.88**	14D		**70.8/3.5**									
K	**2.03**	6D						**98/4.9**					
K	**2.03**	7D			**91.1/4.6**	**91.7/4.6**							

	Rate lb ai/A	Int. Day	1	2	3	4	5	6	7	8	9	10	12-25
L	**2.5**	3D											**181/9**
L	**2.5**	5D			**128/6.4**								
L	**2.5**	7D			**112/5.6**		**113/5.6**						
M	**3.43**	5D					**181/9**						
N	**3.75**	7D				**169/8.4**		**169/8.4**					
N	**3.75**	14 D				**142/7.1**							
O	**4.7 lb**	30 D		**171/8.5**									
P	**5.0**	7D			**224/11.2**	**225/11.2**							
Q	**6.25**	30 D			**226/11.2**								

Table 35. Aquatic Organism Chronic Risk Quotient (Invertebrates RQ/Fish RQ)

(Cheminova and IR4 Supported Max. Tolerance Rates and Scenarios- 0.175 to 1.25 lbs ai/Acre)

	Number of Applications												
	Rate lb ai/A	**Int. Day**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12-25**
A	**0.175**	7D	**inv/fish**									**20/0.2**	
B	**0.50**	NA	**28/0.26**										
C	**0.61**	5D		**57/0.55**	**68/0.65**								
C		7D		**66/0.65**									
C		14D											
D	**0.76**	10D					**100/0.85**						
E	**0.94**	3D	**100/0.5**										
E		6D						**112/1.06**					
E		7D			**104/0.98**				**10.5/0.99**				
F	**1.0**	7D						**112/1.05**					
G	**1.25**	3D	**70/0.66**	**134/1.26**				**223/2.13**					**23/8.7**
G		5D					**163/1.54**						

G		7D			138/1.31	139/1.32	139/1.32	141/1.35 (Aerial)	139/1.32	139/1.3	139/1.3	139/1.3	
G		14D		116/1.13									
H	1.50	7D			166/1.57			166/1.57					
I	1.56	7D		67/1.58			175/1.65						
J	1.88	5D						246/2.32					
J	1.88	7D			208/1.96	21/1.98		21/1.99					
J	1.88	14D		175/1.65									
	Rate lb ai/A	**Int. Day**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12-25**
K	2.03	6D						242/2.29					
K	2.03	7D			225/2.12	226/2.14							
L	2.5	3D											447/4.2
L	2.5	5D			316/3.0								
L	2.5	7D			277/2.6		279/2.7						
M	3.43	5D					200/4.23						
N	3.75	7D				417/3.95		417/3.95					
N	3.75	14D				350/3.3							
O	4.7 lb	30D		422/3.98									
P	5.0	7D			553/5.23	556/5.28							
Q	6.25	30D			558/5.3								

0.175 lbai/A **A10**=Orange, Grapefruit, Lemon, Lime, Tangerine, Tangelo, and Kumquat

0.50 lb ai/A **B1**=Flax

0.61 lb ai/A **C5(5D)**=Sweet Corn **,** **C2(7D)**=Hops, **C3(7D)**=Beans, Corn, Rice, Sorghum, Wheat, and Rye
C2(14D)=Alfalfa, Clover, Lespedeza, Lupine and Vetch

0.76 lb ai/A **D5**=Blueberry

0.94 lb ai/A **E1(3D)**=Grass for hay, **E4(3D)**=Mushroom, **E6(6D)**=Strawberry, **E3(7D)** =Peppermint and spearmint, **E7(7D)**=Macadamia

1.0 lb ai/A **F6(7D)**=Melons, Watermelon, Pumpkin and Winter Squash

1.25 lb ai/A **G1(3D)**=Grass for hay, **G2(3D)=**Field corn **,** **G2(7D)** Brussel sprouts, cauliflower, collards, kale, kohlrabi **G6(3D)**=Mustards**,** **G25(3D)=**Cotton, **G5(5D)=**Watercress, **G3(7D)**=Rice, Sorghum, Wheat, Rye, Barley, Oats and Corn, **G4(7D)**=Blueberry(ULV), **G5(7D)**=Turnip, Broccoli, Apple, Sweet Corn, Beet, Horseradish, Parsnip, Radish, Rutabaga, Salsify,~~Sweet potato,~~ **G6(7D)**= Cabbage and Cherry(ULV), **G7(7D)=**Carrot , **G8(7D)**=Mango and Passion fruit **,** **G9(7D)**=Asparagus **G10(7D)**=Pears and Quince , **G12(7D)**=Guava and Papaya, **G2(14D)**=Alfalfa, Clover, Lupine, Vetch and Lespedenza

1.5 lbs ai/A **H2(7D)**=Celery, **H6(7D)**=Okra

1.56lbs ai/A **I2(7D)**=Potato, Sweet potato, **I5(7D)**=Onion, Garlic, Shallot, Leeks

1.88 lb ai/A **J6(5D)**=Lettuce, **J4(7D)**=Blackberry, Raspberry, Loganberry, Boysenberry, Dewberry, Currant, Gooseberry, **J3(7D)**=Cucumber, Chayote, **J6(7D)**= Strawberry, **J2(14D)**=Grapes

2.03 lbs ai/A **K6(6D)**=Strawberry(50%WP), **K3(7D)**= Spinach, Dandelion, Endive, Parsley and Swiss Chard, **K4(7D)**=Blackberry, Raspberry, Gooseberry, Loganberry, Dewberry, Currant and Boysenberry

2.50 lb ai/A **L25(3D)**=Cotton, **L3(5D)**=Figs, **L3(7D)**=Mustards, Walnuts, and Pecans, **L5(7D)**=Peas

3.43 lb ai/A **M5(5D)**=Tomato, Pepper, Eggplant

3.75 lb ai/A **N4(7D)**=Apricots, **N6(7D)**=Cherry, **N4(14D)**=Peach and Nectarine

4.7 lb ai/A **O2(30D)**=Avocado

5.0 lb ai/A **P3(7D)**=Pineapple**,** **P4(7D)=**Chestnuts

6.25 lb ai/A **Q3(30D)**=Oranges, Grapefruit, Lemon, Lime, Tangerine and Tangelo

Table 36.

PRZM-EXAMS Derived Aquatic RQ's
(EECs Based on 1 in 10 Year Events)

Crop	% of total a.i. applied / year[1]	Use rate (lbs a.i./A)	Interval (days)	No. of applications	Model Results (ppb)				
					PRZM-EXAMS			Acute/Chronic RQ's	
					peak[2]	21d ave	60 d ave.[3]	Inv.	Fish
Cotton	41.6%	Max: 2.5	3	25	291	67.4	47.7	291/674	14.5/11.9
		Typ: 0.3	[3][4]	4	7.9	1.48	0.50	8/15	0.4/0.12
Sorghum	7.4%	Max: 1.25	7	3	26.7	5.01	1.95	27/50	1.3/0.5
		Typ: 0.8	[7]	1	2.94	0.50	0.18	3/5	0.15/0.05
Apple	2.14%	Max: 1.25	7	5	0.80	0.33	0.19	0.8/3	0.04/0.05
		Typ: 0.7	[7]	3	0.59	0.24	0.09	0.59/2	0.03/0.02
Citrus	0.49%	Max: 6.25	30	3	156	23.2	10.7	156/232	7.8/2.7
		Typ[5]: 2.5	[30]	1	42.6	6.65	2.33	47/67	23.6/0.6
Lettuce	0.45%	Max: 1.88	5	6	15.4	6.26	2.98	15/63	0.8/0.74
		Typ: 2.0	[5]	1	5.63	1.58	0.56	6/16	0.3/0.14

PRZM EXAM Runs Correspond to the Following Use Scenario Numbers :

1.25 lb ai/A **G3(7D)**=Rice, **Sorghum**, Wheat, Rye, Barley, Oats and Corn, **G5(7D)**=Turnip, Broccoli, **Apple**, Sweet Corn, Beet, Chayote, Horseradish, Parsnip, Radish, Rutabaga, Salsify, **G2(14D)**=**Alfalfa**, Clover, Lupine, Vetch nd Lespedenza

1.88 lb ai/A **J6(5D)**=Lettuce

2.50 lb ai/A	**L25(3D)**=Cotton
6.25 lb ai/A	**Q3(30D)**=Oranges, Grapefruit, Lemon, Lime, Tangerine and Tangelo

Table 37. MALATHION NON AGRICULTURAL USE-Maximum Labeled Rates
Worst Case EECs and RQs Direct Application to Water or 100% Drift*

USE LOCATION **(Predicted U.S. Acreage)**	**Max. Rate lbs ai/A**	**Max # Applic.**	**Min. Interv**	**Acute Aquatic EEC s 0.5-6 ft**	**Acute Aquatic Risk Quotient**
Nonagricultural rights of way/fencerows/hedgerows (17,000 acres)	0.598	NS	NS	438 to 36 ppb	Inv.-438 to 36 Fish-22 to 1.8
Mosquito Control (8,227,000 acres) Lakes/Ponds/Reservoirs(human use)(0.5985) Nonag. Uncultivated Areas/Soils (0.6) Polluted Water (0.6) Lakes/Ponds/Reservoirs (No Human Use) (0.628) Swamps/Marshes/Wetlands/Stagnant Water (0.628) Intermittently Flooded Areas/Water (0.628)	0.630 ULV Aerial	NS	NS	462 to 38 ppb	Inv.-462 to 38 Fish-23 to 1.9
	0.630 Grnd Fogger	NS	NS	92.4 to 7.6 ppb (20% drift)*	Inv.-92 to 8 Fish-4.62 to 0.4
Woodland Use (17,000 acres) Pine Forest/Shelterbelt (0.9375) Eastern White Pine (Forest) (0.9375)	0.94	NS	NS	688 to 57 ppb	Inv.=688 to 57 Fish=34.4 to 2.8
Rangelands/Pastures/Set Aside Acreage/Summer Fallow (1,625,000 acres) Canarygrass (1.2) Rangeland or Pastures (1.25) Grass Forage/Fodder/Hay (1.25)	1.25	NS	NS	917 to 76 ppb	Inv.=917 to 76 Fish=46 to 3.8
Ornamental Plant Uses-Nurseries-Homeowner (175,000 acres) Ornamental trees and Herbaceous Plants	1.746	NS	NS	direct drift unlikely	Not computed
Ornamental Nonflowering Plants Ornamental Woody Shrubs and Vines (2.5)	2.50	NS	NS	direct drift unlikely	Not computed
Commercial Tree Production (no est. acreage) Christmas Tree Plantations, (3.125) Ornamental and/or Shade Trees (3.125) Slash Pine (forest) (3.125)	3.125	NS	NS	2293 to 190 ppb	Inv.=2293 to 190 Fish=114.6 to 9.5
Public Parks (67,000 **acres)**	NS			Rates not specified	Not computed
Turf Use/ Golfcourses/Commercial Lawncare Ornamental Lawns and Turf	5.1	NS	NS	direct drift unlikely	Not computed
No Non-Ag uses at higher rates (>5.1 lb ai/A)	Not supported				Not supported

NS=Not Specified

*Drift from truck mounted foggers is not expected to exceed 20% deposition due to continuous drift of micro droplets on air currents.

Endangered Species

Endangered species LOCs are exceeded for malathion for acute hazard to endangered fish, aquatic inverebrates, and insects for most outdoor uses. Chronic hazard LOC’s to threatened birds, mammals, amphibians and reptiles are potentially exceeded for certain uses. Chronic hazard LOC's for endangered fish and invertebrates are exceeded by most uses. The magnitude of malathion use and the numbers of potentially exposed endangered species will require more extensive analysis by the OPP Endangered Species Branch.

The Endangered Species Protection Program is expected to become final in the future. Limitations in the use of malathion will be required to protect endangered and threatened species, but these limitation have not been defined and may be formulation specific. EPA anticipates that a consultation with the U.S. Fish and Wildlife Service will be conducted in accordance with the species-based priority approach described in the Program. After completion of consultation, registrants will be informed if a required label modifications are necessary. Such modifications would most likely consist of the gener label statement referring pesticide users to use limitations contained in county Bulletins.

Risk and Exposure Characterization

The following section identifies major routes of exposure expected to lead to effects on ecological resources and the highest exposure levels for drinking water sources. These are direct aerial applications to large areas, spray drift, and runoff in nonagricultural settings. The use patterns of highest Agency concern are those expected to cause the highest off-target EECs of malathion and malaoxon.

Summary of Expected Paths of Potential Exposure for Wildlife

Direct Application Public Health Use
Aerial and ground spray applications of malathion allow for coverage of large areas of urban, suburban, and rural areas. For instance malathion may be applied aerially "...over cities, towns, and other areas...." (Fyfanaon ULV Insecticide label) for adult mosquito control. Rates of malathion use for mosquito control are up to 9.9 lbs ai / mi^2 / year in the following states: Washington, Oregon, Utah, Wyoming, Texas, Louisiana, Mississippi, Michigan, Alabama, Florida, Georgia, South Carolina, North Carolina, New Jersey, and Virginia. In some areas urban and agricultural use of malathion may overlap. Terrestrial wildlife, insect, and adult amphibian exposure from this type of use is expected to be through a multitude of food sources receiving residue including vegetative food matter, insects, drinking water and also through direct dermal and inhalation exposure to spray applications. Aquatic exposure to fish, crustacea, mollusca, arthropoda, and larval amphibia is expected to be primarily from drift with lesser amounts contributed by runoff.

Malathion for adult mosquito control is applied by fogging and aerial methods. Thermal aerosols or fogs create very small droplets of malathion (<20μm) that can be carried on air currents for long distances before contacting plants, water, or soil. Because of this tendency, malathion in fogs is expected to dissipate largely through atmospheric diffusion with relatively little deposition onto water soil. Wang *et al* (1987) studying fenthion fog deposition on water measured 5-6% deposition of the applied insecticide. EFED has used a more conservative estimate of 20%. For aerially applied ULV formulations higher deposition is expected because droplet size is larger (up to 100μm) and there are n specified protective buffer zones. Thus it is assumed by EFED that 100% deposition occurs in shoreline areas. Based on low toxicity thresholds of 0.5 ppb (invertebrates) to 10 ppb (fish), 20% to 100% drift scenarios, actual monitored residue levels and observed adverse effects in actual use situations risk quotients for aquatic invertebrates and fish are expected to be exceeded.

In areas close to the fogging apparatus or beneath aerial applications inhalation may be an important route of acute exposure for terrestrial wildlife. Mammalian toxicity data provided to HED show sever effects to rats in the lowest exposure group of 0.1 mg/l (96 h). The no effect level is not defined and it is not known what interspecies differences in sensitivity exist. Although it is not clear what atmospher malathion concentrations are acceptable, the levels generated during mosquito control are expected to be very transient. Direct exposure to flying non-target insects is not only likely, but probably unavoidable as fogging type applications are designed to contact flying insects.

Ground and Airblast Application to Agricultural Sites

Normal malathion ground application usage in agricultural field settings presents chronic risks for terrestrial wildlife, but lower risk to aquatic life. Key issues identified are possible chronic effects resulting from repeated 3 to 7 day pulse exposure of birds to malathion at certain rates of application, increased risk to wildlife resulting from exposure to malathion products containing mixtures of other insecticides and fungicides, and direct contact toxicity to beneficial insects from off target drift from agricultural target areas or later contact with residual malathion residues on the target crops. Some toxic exposure to aquatic organisms from small amounts of runoff is expected, though exposure from spraydrift will be less than for aerial application.

Synergistic toxicity resulting from coexposure to malathion and other pesticides has been noted in previous portions of this review. Not only are malathion mixtures with other pesticides marketed as end-use products, but agricultural use of malathion is commonly accompanied by the use of other pesticides in the same field leading to mixtures of residues in the field. Runoff and drift of malathion a mixes with residues of many other pesticides used in fields adjacent and in the same drainage basin. Some cholinesterase inhibiting insecticides are expected to result in additive toxicity when combined with malathion, although some other pesticides have been shown to potentiate malathion toxicity. Greater than expected toxicity has been noted with certain cholinesterase inhibiting insecticides (including carbaryl and EPN) and some fungicides (including clotrimazole). The environmental and ecological effects of mixtures is poorly understood, but in many instances, increased sensitivity of organisms is expected. More data concerning the toxicities of these end-use product mixtures as well as mixture with other pesticides in normal agricultural use is needed to assess these concerns for malathion.

Spray Drift from Agricultural Uses

Monitoring results show that spray drift can be a major source of aquatic contamination. Drifting malathion applications carried by air movement will reach unintended sites. More than half of the malathion usage in the United States is applied in ULV formulations which are highly prone to drift when applied aerially. ULV formulations are popular with aerial applicators because they are very concentrated and allow the treatment of large acreages without returning to the airfield for refilling or refueling.

An assessment of drift as a result of malathion use methods for the Boll Weevil Eradication Program (presently 60% of all malathion use in U.S.) was conducted by measuring off-target drift adjacent to aerial ULV malathion applications (Penn State 1993). Application conditions were the same as those used in the eradication program. The spray system was a conventional boom and nozzle system fitted with Spraying Systems stainless steel 8002 Flat Fan spray tips. The nozzle position was straight down and the flying height was a nominal 5 feet above the crop canopy. Drift was measured from single aircraft passes delivering 1 lb/A. Wind direction was perpendicular to the flight path. Seventeen runs were conducted under varying meteorological conditions. Maximum depositions were 21, 12, 2.8, and 0.7% of the expected maximum at 100, 200, 300, and 1000m downwind (Penn State 1993). The highest amount of drift at 1 km occurred when atmospheric conditions were stable, meaning vertical ai mass movements are dampened. Higher drift levels at shorter distances occurred under unstable, windy conditions. Averages of results under different atmospheric conditions show deposition of 9.4% at 100 m while at 1000m the deposition rate was 0.08%.

Using deposition rates from the Penn State study it is possible to calculate aquatic EECs for varying depths of water based on direct application of the expected % of drift and using a 6 inch to 6 foot depth range for the standard 1 acre farm pond scenario.

Table 38. Maximum downwind drift aquatic EECs and risk quotients

water depth (in)	100 m (21% deposition)			200 m (12% deposition)			300 m (2.8% deposition)		
	EEC	RQ (fish)	RQ (daphnid)	EEC	RQ (fish)	RQ (daphnid)	EEC	RQ (fish)	RQ (daphnid)
6	154	7.7	154	88	4.4	88	20.5	1.0	20.5
72	25.6	1.28	25.6	7.3	0.37	7.3	1.7	0.1	1.7

Based 1 lb/acre (used in the Penn State drift study) drifting to a one hectare pond.
Risk quotients are based on fish LC50 for bluegill (20 ppb) and *Daphnia magna* LC50 (1 ppb).
The effects of reducing spray drift was examined two ways: first, varying the drift parameters in PRZM EXAMS modeling and, second, by comparing the effect different application practices and buffer strips on measured drift in monitoring studies.

Levels of concern for fish are exceeded at 100 and 200 m distances with these maximum drift values. At 300 m a level of safety is achieved for fish, but daphnids are still at risk. Monitored values of malathion drift to streams suggest that table above is conservative in estimating aquatic risk. A typical range of monitored values is shown in Table 13a ranging from non-detected to almost 11 ppb 25 feet from the field. In these applications wind direction was away from the water.

The Boll Weevil Eradication Program mostly uses ultra low volume (ULV) formulations in its program in several states. ULV which is ~95% malathion is the most cost effective formulation in the treatment of cotton for boll weevil because it is concentrated and enables aerial applicators to treat large areas before refueling and refilling. ULV applications results in the formation of small droplets of the pestic which are prone to drift long distances. The speed by which droplets fall is exponentially dependent upon their size such that small droplets fall very slowly. Smaller droplets result in more nontarget deposition of pesticide through drift caused by wind, thermal air currents, and turbulence from applicator planes. Presently at least 14 different crops receive aerial ULV applications of malathion. These crops include alfalfa, blueberries, clover, cotton, dry beans, corn, sorghum, grass, lima beans, oranges, rice, snap beans, wheat, and cherries. Drift from non-ULV formulations is significantly lower under analogous application conditions.

Monitoring studies suggest that reducing drift dramatically reduces aquatic EECs. Boll weevil treatments were examined for drift to surface water in the Southeast and Texas. Table 12a shows the effects of ground versus aerial application and varying buffer strips on malathion drift by measuring concentrations before and at 15 minute increments after application. Four different sites are examined with buffer strips ranging from 700 feet with 30-60 foot trees to 25 feet with low-lying vegetation. Fiv other sites shown in previous tables related to actual field monitoring results provide additional information on drift but lack site and application information which led to the monitored residue levels

Monitoring data suggests that wider buffer strips and ground applications reduce drift. Aerial applications to two fields with 125 foot or greater buffers resulted in no measured drift. Aerial applications to a 95.3 acre field with a 100 foot buffer containing mature hardwoods (Pursley Creek site) resulted in minor drift: only three measurements of six total were greater than 3 ppb above background. Four aerial applications to a 19.2 acre field with a 25 foot buffer containing low kudzu vegetation (Stewart Creek) resulted in significant drift: all four events resulted in aquatic concentration exceeding 3 ppb.   Five ground applications to the same site resulted in low drift: four of five ground applications resulted in aquatic concentration of less than 0.33 ppb.

Runoff in Urban Scenarios

Though initial exposure of non-target aquatic habitats is expected to be primarily through spray drift, monitored residue levels in residential storm water runoff events have yielded high residue levels, despite the short terrestrial half-life values that are reported for malathion.

It should be noted that monitored runoff events in urban areas reflect aggregate malathion residues resulting from all uses of malathion in that particular drainage basin such as homeowner use, commerci turf use, municipal mosquito control use, and commercial agricultural use. There are approximately 6(home and garden products containing malathion and malathion/methoxychlor on the market.

Monitoring data of runoff from urban-use sites is frequently high probably due to increased runoff fro impermeable surfaces and increased persistence on microbially inactive, dry surfaces. The fastest routes of malathion degradation are through aerobic metabolism and hydrolysis. Residential surfaces such as asphalt and concrete, which malathion is likely to contact in urban use, do not provide microbes and moisture required for these degradation pathways. A CalEPA study and monitoring data also suggest that the toxic degradate malaoxon is more likely to form on residential surfaces and occur mo frequently in urban runoff. Anthropogenic surfaces are less likely to retain malathion during rainfall which would lead to pulses of malathion in storm water runoff which drain into urban streams. USGS NAQWA data show higher levels of malathion and more detects in urban streams than were monitored in rural and agricultural counterparts. In medfly control efforts south of San Francisco in 1984 residue levels increased significantly after rainfall events. Fish kills coincided with high levels of malathion (8 800 ppb) after rainfalls. Application rates and methods for mosquito control and medfly programs are similar, thus runoff resulting from urban mosquito control operations may be similar to those observed from medfly applications. Malathion is used in community mosquito control programs in at least 15 states up to 9.9 lbs / mi^2 / year. This assessment indicates that risk to aquatic life from runoff transported residues will be high in urban use scenarios.

Runoff in Agricultural Scenarios

Agricultural field runoff of malathion to nontarget aquatic habitats has been observed to be generally low, probably due to rapid degradation on soil. Runoff monitored in the Boll Weevil Eradication Program suggests that a majority of malathion levels in receiving waters will not present a significant r for fish. The risk level for invertebrates from runoff is less clear. Malathion in runoff from cotton fiel ranged from none detected to 146 ppb in undiluted drainage. Dilution of runoff and therefore the degree of risk for invertebrates will vary with the size of the body of receiving water. A dilution facto of nearly 300 is necessary to reduce the daphnid RQ to below 0.5. This would be expected in larger receiving water bodies but agricultural field runoff to small streams and ponds will result in higher risk

Malathion Non-Crop Usage in Rural Scenarios

Malathion is used in a variety of settings which are rural in nature, but not related to a particular crop. Malathion ULV uses include aerial and ground application to control grasshopper and beet leafhopper on pasture lands, rangeland, "non-agricultural" lands(wasteland and roadsides), fencerows, feed-lots, clover(usually a cover crop) and summer fallow. In addition malathion ULV labels list woodland uses via aerial application to control forest insects on douglas fir, true fir, spruce, hemlock, pine, and larch trees to control budworms, looper, sawfly, spittlebug and larch casebearer. Registrants have stated an intention to remove forest uses, but this may not apply to privately owned wood lots and wooded lands. These use patterns are similar to mosquito control scenarios in that they are not directed at any particular field site, yet labeling language does not include specific instructions to aid in protection of sensitive aquatic habitats contained within these areas nor do they specify maximum seasonal application restrictions. They are also similar to agricultural sites in that soil degradation is likely to b more pronounced than in urban scenarios. The total acreage of these types of use sites will total over 2 million acres on a yearly basis.

Exposure risk to avian and mammalian species from repeated applications with narrow intervals is therefore concluded to exist for these use scenarios. Exposure risk from runoff is likely to be equivalent to or perhaps less than agricultural crop sites which presumably might have more bare soil surfaces. Danger of off target drift and to some extent runoff (grasslands) to aquatic habitats may be reduced by foliar intercept in some cases. However, without precautions such as buffer zones to protect bogs, potholes, streams, marshes and other aquatic habitats common to these areas it is assumed that direct drift contamination to these habitats may occur with detrimental effects to aquatic vertebrates and invertebrates. Protection of beneficial or endangered insects with such applications would appear to be impossible. It is therefore assumed that acute risk to non-target insects will occur.

Spatial Distribution of Potentially Effected Habitats and Species Groups

Terrestrial Wildlife Utilization of Major Malathion Usage Areas

The following summary of potential major exposure areas for malathion usage is based on EPA Quantitative Usage Analysis data prepared in 1997. Maximum usage estimates were used to allow for potential shifts in market usage of malathion products. Species expected in various crop scenarios were drawn form Wildlife Utilization of Croplands, Gusey, William F. And Z. Maturgo, 1973. The purpose of this portion of the document is not to categorize every species type that could conceivably be exposed to the vast number of potential malathion use sites, but instead to provide a general overview of the species types which might be present for crop and non-crop use sites and to categorize which areas of the country (where possible to predict) may be most heavily impacted by the type of use pattern. Aquatic species are too numerous to list so habitat types common to use sites were listed instead.

Table 39. Terrestrial Wildlife Utilization of Major Malathion Usage Areas

Crop Group	**Maximum Usage**(acres)	**Major States for Malathion Usage**	**Species Common to Usage Locations**
Berry Crops (Blueberry, blackberry, strawberry, etc)	70,000	OR, MI, NJ, WA, CA	waterfowl, quail, pheasant, crows, blackbirds, songbirds(finches, robins, starlings, cedar waxwing), grouse, rabbits, deer, racoon, woodchuck, skunk, opossum,
Citrus Crops	14,000	FL, CA, AZ	doves, roadrunner, screech and horned owls, hummingbirds, gilded flicker, laderbacked woodpecker, western kingbird, verdin, cactus wren, mockingbird, thrashers, orioles, cardinals, grosbeaks, goldfinch, linnet, deer, raccoon
Pome Fruits(apple, pear), Avocado, Figs, Grapes	102,000	WA, MO, MI, TX, GA, CO, CA, TN, FL, MS, OH, AZ	grouse, pheasant, songbirds(bluebird, cardinal, catbird, flicker, blue jay, kingbird, magpie, mockingbird, phainopepla, robin, fox sparrow, thrashers, thrushes, vireos, cedar waxwing, woodpeckers), hawks, bear, fox, marmot, porcupine, rabbit, deer, quail, flicker, racoon, opossum, partridge
Stonefruits (apricots, cherries, peach, nectarine)	64,000	OR, WA, GA, TX, AL, MS, MO, CA, AZ	doves, songbirds(blackbirds, grosbeaks, cedar waxwings, robins, starlings western tanager, brown thrasher, titmouse, orioles, jays, finches, etc), pheasant, wild turkey, rabbit, deer, fox, opossum, raccoon, squirrel,
Nut Trees	57,000	CA, TX, LA, GA, OK	
Bulb vegetables (onion, garlic, etc)	37,000	CA, UT, MI, ID, GA	pheasant, rabbit, deer, songbirds, dove

Leafy, Legume, Tuber and Root, Fruiting, Cucurbit and Other Vegetables	315,000	CA, TX, AL, MI, FL, OH, NY, IL, AZ, MS, MO, MN, WI, ID, IN, WA, OR, VA, NC, WV, UT, NJ, GA	turkey, California, scaled, valley, and bobwhite quails, songbirds(buntings, larks, pidgeon, sparrows, roadrunner, grosbeak, ground doves, pipits), shorebirds, coots, ducks, geese,crows, doves, sandhill crane, prairie chicken, partridge, owls and hawks(feeding on field rodents), coyote, muskrat, gray squirrel, groundhog, elk, skunk, rabbits, raccoon, opossum, woodchuck, deer,
Cereal Grain Crops (barley, corn, rice, wheat, sorghum, oats, rye, rice)	697,000	GA, CO, TX, AZ, KY, VA, MN, MT, NC, ND, CA, NY, NC, PA, TX, AR, MS, LA, KS, MO, NE, SD, TN, OK,	rabbits, pheasant, pigeon, doves, ducks(black, canvasback, mallard, pintail, ringnecked, shoveler, teal, wood), coots , rails, egrets, herons, ibis, and gallinules(rice fields), geese, swan, songbirds(blackbirds, towhees, thrasher, sparrows, junco, magpie, snow buntings, grosbeaks, jays, cardinal, bobolink, meadow and horned lark),woodpeckers (eat seeds), ravens, grackles, crows, partridge, grouse, scaled and bobwhite quail, sandhill crane, Attwater prairie chicken(TX), deer, elk, antelope, wild turkeys, gray, fox and ground squirrel, woodchuck, fox, porcupine, coyote, moles, whitefooted and pocket mice, kangaroo rat, muskrat, javelina(TX)
Cotton + USDA Bollweevil	796,000	TX	deer, turkey, squirrel, rabbit, quail, dove, pheasant, prairie chicken, raccoon, oppossum, sandhill crane, antelope
Grass and Non-grass Forage Crops (alfalfa, clover, hay)	605,000	CA, ID, MT, OK, AZ, KS, TX, MO, SD, KY	pheasant, mourning dove, partridge, quails, ducks, Canada geese, elk, deer, antelope, grouses, prairie chickens, rabbits, turkey, songbirds, cranes, skunk, small mammals, marmot, ground squirrels,
Hops		OR, WA	pheasant, quail, songbirds, doves, owls and hawks feeding on small mammals
Mint	31,000	IN, WI, OR, WA(90%)	pheasant, quail, doves, songbirds, partridge
Pasture lands	47,000	LA, MO, FL, GA, TX, MS	field and vesper sparrows, bobolink, meadow and horned lark, goldfinch, swallows, pipit, cowbird, red polls, juncos, longspurs, blackbirds, crows, nighthawk, whippoorwill, yellow, palm and prairie warblers, grackles, flickers, bluebirds, and indigo bunting.
Private Lots/Farmsteads	66,000	FL, CA, SD, AL, OK, KS (60%?)	No definitive state surveys were reviewed.
Set Aside Acreage	665,000	MT, MN =(90%?)	No definitive state surveys were reviewed
Summer Fallow	893,000	MT, TX = (100%)	No definitive state surveys were reviewed
Rangeland	20,000	TX, FL, CO =(85%)	No definitive state surveys were reviewed
Woodlands	17,000	AL, LA, TN=(81%)	No definitive state surveys were reviewed
NON Agricultural			

Roadways and fencerows	17,000	Nationwide	sparrows, kingbirds, flycatchers, yellowbreasted chat, indigo bunting, bluebird, goldfinch, brown thrasher, catbird, robin, woodpeckers, yellow and palm warblers, and vireos.
Golf Courses	>12,000	Nationwide	Waterfowl including snow and Canada geese (may feed on treated turf), squirrels and other small mammals(in rough areas), ground feeding songbirds, ie robins,
Nurseries	175,000	Nationwide	
Parks	67,000	Nationwide	Many types of songbirds, small and large mammals,
Landscape Contractors- Bldg Perimeters/Grounds	No estimates	Nationwide-Urban	Songbirds
Cemeteries	21,000	Nationwide -Urban	Same as parks
Mosquito Control	8,227,000	Nationwide near population centers, particularly those surrounded by static aquatic settings ie beach resorts, lake shore communities, low water or flood prone areas	Saltmarshes: Bank and tree swallow, fish and common crow, savanna, seaside, and Sharp tailed sparrowl, redwing blackbird, horned lark, egrets, rails, shorebirds, gulls, herons, gallinules, other waterfowl, muskrat, otter, Freshwater marshes and wet woodlands: marsh, winter and Carolina wrens, swamp, Savanna, sharp-tailed sparrows, swallows, water thrush, ovenbird, phoebe, wood pewee, veery, bluegray gnatcatcher, yellow breasted chat, warblers(hooded, yellowthroat, blackcapped, and Wilson's), racoon, muskrat, beaver,
Proposed for Revocation of Uses Soybean, Peanut, Sunflower	226,000	GA, OK, NC, FL, TX, TN, MN, MO, IN, AR, KS, SD, ND	Species groups not categorized due to impending revocation of use on these crops

<u>Aquatic Organisms: Utilization of Habitats Exposed to Malathion Usage</u>

Numerous types of agricultural uses of malathion may border valuable aquatic habitats such as streams, rivers, lakes, and freshwater marshes. Many of these tributaries may drain to estuarine areas. A few of the crop uses may actually involve sites which border estuarine areas (ie citrus). In some cases, irrigation canals near crop sites will contain fish and shrimp populations and also drain to natural water sources. In general, malathion incidents have involved pulse loading of malathion to streams and ponds following heavy rainfall events or aerial spraydrift of residues directly to the surface of standing water bodies. Residue detection in sediments has been rare. In urban scenarios, storm water runoff has provided a point-source type of residue contribution to streams which drain these areas. Malathion poisonings of aquatic organisms are most likely to occur in the early hours of the exposure period immediately after rainfall or spray applications to
specific sites. The numbers of species potentially effected is large and the types of habitat exposures quite varied. The following table provides a very general overview of the types of aquatic habitats that are expected to be exposed from various uses of malathion.

Table 40. Aquatic Habitats - Use Associations			
Crop Group	**Maximum Use**(acres)	**Major States for Malathion Usage**	**Habitats Common to Usage Locations**
Berry Crops (Blueberry, blackberry, strawberry, etc)	70,000	OR,MI,NJ,WA,CA	FW Marshes, ponds, and streams:
Citrus Crops	14,000	FL, CA, AZ	Irrigation canals, rivers, freshwater springs, some estuaries
Pome Fruits(apple, pear), Avocado, Figs, Grapes	102,000	WA, MO, MI, TX, GA, CO, CA, TN, FL, MS, OH, AZ	FW streams, rivers, ponds, marshes, and lakeshore
Stonefruits (apricots, cherries, peach, nectarine)	64,000	OR, WA, GA, TX, AL, MS, MO, CA, AZ	FW streams, rivers, ponds and marshes
Nut Trees	57,000	CA, TX, LA, GA, OK	Streams, irrigation canals, and rivers
Bulb vegetables (onion, garlic, etc)	37,000	CA, UT, MI, ID, GA	Streams, rivers, bogs
Leafy, Legume, Tuber and Root, Fruiting, Cucurbit and Other Vegetables	315,000	CA, TX, AL, MI, FL, OH, NY, IL, AZ, MS, MO, MN, WI, ID, IN, WA, OR, VA, NC, WV, UT, NJ, GA	Irrigation canals, streams, rivers, bogs, marshes
Cereal Grain Crops (barley, corn, rice, wheat, sorghum, oats, rye, rice)	697,000	GA, CO, TX, AZ, KY, VA, MN, MT, NC, ND, CA, NY, NC, PA, TX, AR, MS, LA, KS, MO, NE, SD, TN, OK,	Streams, rivers, ponds, prairie potholes, marshes, saltmarshes, estuarine bays
Cotton + USDA Bollweevil	796,000	TX	Rivers, streams, possibly marshes
Grass and Non-grass Forage Crops (alfalfa, clover, hay)	605,000	CA, ID, MT, OK, AZ, KS, TX, MO, SD, KY	Ponds, bogs, marshes, streams, prairie potholes
Hops		OR, WA	rivers and streams
Mint	31,000	IN, WI, OR, WA(90%)	Streams
Pasture lands	47,000	LA, MO, FL, GA, TX, MS	Streams, rivers, ponds, prairie potholes, marshes, swamps
Private Lots/Farmsteads	66,000	FL, CA, SD, AL, OK, KS (60%?)	Streams, ponds, bogs, potholes, FW springs
Set Aside Acreage	665,000	MT, MN =(90%?)	Streams, ponds, lakes, marshes and potholes
Summer Fallow	893,000	MT, TX = (100%)	Streams, rivers, and potholes
Rangeland	20,000	TX, FL, CO =(85%)	Streams, rivers, swamps, FW springs
Woodlands	17,000	AL, LA, TN =(81%)	Streams, bogs, rivers, wooded wetlands
NON Agricultural			

Roadways and fencerows	17,000	Nationwide	Drainage ditches, crossing or adjacent streams and rivers, swamps, saltmarshes, ponds
Golf Courses	>12,000	Nationwide	Ponds, streams, marshes, some saltmarsh areas
Nurseries	175,000	Nationwide	Ponds, drainage areas to streams
Parks	67,000	Nationwide	Streams, ponds, and lakes(inland) , saltmarshes and ocean shorelines(coastal)
Landscape Contractors-Bldg Perimeters/Grounds	No estimates	Nationwide-Urban areas	Retention and natural ponds, streams, drainage from storm sewers to tributaries
Cemeteries	21,000	Nationwide-Urban areas	Ponds and streams
Mosquito Control	8,227,000	Nationwide near population centers, particularly those surrounded by static aquatic settings ie beach resorts, lake shore communities, low water or flood prone areas	Saltmarsh mosquito control-saltmarshes, estuarine bays, mangrove swamps, shoreline areas Freshwater mosquito control: freshwater marshes, bogs, and wet woodlands:(Inland areas near population centers
Proposed for Revocation of Uses Soybean, Peanut, Sunflower	226,000	GA, OK, NC, FL, TX, TN, MN, MO, IN, AR, KS, SD, ND	

Adequacy of Malathion Toxicity Data

The toxicological data, though extensive for malathion, is not complete in several key areas. In addition, much of the data is over twenty years old, and, to some extent, was not conducted in accordance with stricter standards which are required of studies presently submitted to support registration of pesticides. One example would be the fact that most of the acute toxicity endpoints for aquatic organisms are based on nominal concentrations which, due to malathion's short aquatic persistence, may not be appropriate since this could lead to calculated LC50 values which are higher than would have been estimated if based on mean measured concentrations.

There are also some other areas where the data set is weak. In formulation testing only one presently employed product formulation (57% EC) was tested on 4 species (daphnid, oyster, honeybee, and sheepshead minnow). There are no submitted toxicity data on the mixture of malathion and methoxychlor, a possibly highly lethal cocktail for aquatic life. There are no studies regarding the chronic effect levels of malathion to estuarine fish or invertebrates which could conceivably be expos to repeated pulse load exposures for such uses as citrus and cotton. Further data to elucidate potential effects to non-target insect populations is needed. Acute studies with honeybees indicate that acute contact with direct or latent residues may prove lethal for several days after application. Other beneficial insect populations may also suffer acute losses. There is some indication that amphibian lif cycles could be effected by malathion exposure. Though not presently a data requirement requested by the Agency, but given what is known about acute and chronic effect levels observed in frogs, a better understanding of effects to this taxa is needed to improve this assessment.

Sublethal effects caused by temporary disruption of nervous system functions are difficult to use in present risk assessment procedures, because so little is known about their ultimate effect on non-targe species populations. However, malathion has been shown to disrupt nesting success in sharp tailed grouse, loss of ability of laboratory mice to navigate a maze, and loss of swimming ability for fish swimming against a current. All of these effects theoretically could lead to reduced survival of certain species groups, when combined with the normal stress factors associated with survival (eg. successful rearing of young, escape from predators, and navigation to spawning grounds).

Limitations of Monitored Effects
Though a large number of incidents associated with adverse effects to aquatic vertebrates near malathion use sites have been reported, very little information regarding effects to invertebrate populations in the same sites was provided. Given the lower toxicity thresholds for invertebrates exposed to malathion, it is expected that lethal effects to these populations are now occurring from present uses, but, due to the difficulty in observing these effects, go unreported. Many of the monitore residue levels in aquatic habitats near malathion use sites have far exceeded 0.5 ppb which is considered a toxicity threshold for acute effects to aquatic invertebrates. Chronic effects were observed in laboratory studies on daphnids at concentrations which are considered the limitation of detection in field monitoring studies (0.1 ppb). Another consideration is that many of the adverse effects reported for malathion are not investigated within the first 48 hours of exposure, thus allowing substantial degradation of the initial peak concentrations which caused the acute reaction observed in the effected organisms.

Characterization of Predicted Effects to Nontarget Species from Malathion

Ecological Risk to Birds and Mammals
Based on estimated risk quotients for dietary exposure scenarios malathion is not expected to offer significant acute hazard to birds even at the proposed maximum application scenarios of 6.25 lbs ai/acre on citrus.

Sublethal effects to birds (reduced AChE levels) will, in all probability, result from exposure to malathion residues. The effects may not in themselves prove lethal, but the ultimate result may prove t be reduced survival when exposed birds are subjected to other stress factors in the environment. When radio-tagged sharp-tailed grouse were sublethally dosed with dieldrin or malathion and released back into the wild significant reductions in ability to nest, reproduce and possibly escape predators were observed up to 12 days after dosing (McEwen and Brown, 1966). Control birds all survived and reproduced successfully. In field exposures of birds to malathion applications singing activity was reduced or ceased for up to 2 days following the application.

Chronic exposure for birds presents another matter. In general, malathion is not deemed to be a persistent compound. However, because of the fact that there are no clear restrictions on most of the present labels regarding numbers of consecutive applications, intervals, or avoidance of nesting birds it is conceivable that birds may be subjected to repeated peak levels within very short time intervals. The chronic effects to egghatch and viability were observed in bobwhite quail at 350 ppm dietary levels. The NOEC for this study was 110 ppm. This threshold would be crossed at application rates above 1.0 lb ai/acre, particularly with short intervals between applications. As this type of effect is usually observed early in the study it might be surmised that the effects in the field would result from early init exposures to malathion as opposed to growth effects which might require a longer exposure period.

Acute and chronic reproductive effects to mammals are not expected at the proposed tolerance rates. Sublethal effects to nervous system functions caused by acetocholinesterase blockage may lead indirectly to reduced survival. In studies where test rats were exposed to malathion, reduced ability to navigate a maze was observed (Desi, 1976). This could be serious if a small mammal's ability to relocate its shelter left it exposed to predators or unable to return to its young.

Risk to Invertebrates

The modeling results and field monitored residues indicate that aquatic acute high risk, restricted use, and endangered species levels of concern are exceeded by 8 to 80 times for freshwater and marine invertebrates at application rates at 0.175 lb ai/A, the lowest rate labeled for malathion. For the higher rates the acute risk LOC's are exceeded by over 400 times. The chronic level of concern is far exceeded at all application rates for malathion. Monitored levels of malathion have frequently (though not always) been observed at concentrations which would far exceed the 0.5 ppb level of concern for acute toxicity to invertebrates. In Florida, monitored background levels in urban ponds sometimes exceeded this level of concern **before** aerial applications for medfly control were made. During 1994 95 Medfly spraying efforts in Ventura County, California samples were taken from streams in the spray area after rainfall events and subsequently used in toxicity studies with the freshwater cladoceran, *Ceriodahpnia dubia* and the estuarine mysid, *Neomysis mercedis* (Fujimura, 1995-see summary in appendices). Samples taken during a storm event proved 100% toxic to all exposed test organisms within 2 to 24 hours. These results indicate that concerns for invertebrate survival in exposed urban streams and estuaries are warranted. Monitoring programs related to bollweevil eradication efforts in southeastern states have also yielded residue levels which would be considered to offer acute risk to invertebrates. In general, levels monitored in agricultural settings appear to be lower than in urban settings and therefore exceedances may be less severe and less frequent under agricultural scenarios. However, predicted EEC's still indicate potential hazard to inverebrates from most crop uses from spraydrift (when applicable) or runoff.

Risk for Fish

Risk quotients indicating levels of concern for acute risk to fishes , restricted use, and endangered species are exceeded for freshwater and estuarine fish at registered application rates of 0.5 lb ai/A, <0.175 lb ai/A, and <0.175 lb ai/A, respectively. Based on monitored residues, this will prove more likely if no protective restrictions are employed. The labels presently do not include actual protective methods (eg. buffer zones) for prevention of drift to aquatic habitats. Due to malathion's low persistence characteristics in water, chronic exposure risk for fish is less likely for single applications Repeated applications could lead to continual exposure to peaks within one week periods, allowing for mean levels to remain above the chronic threshold of 2 ppb for early life stage effects. In actual uses c malathion (both urban and agricultural) many fish kills have been reported and confirmed. These incidents generally involve drift from aerial applications to small ponds, inland lakes, and rivers. In mc cases the residues have not remained at high levels following these fish kills, indicating that fish are severely effected early in the exposure period. Fish kills resulting from runoff have also occurred several days after applications have been completed. These kills generally involve concentration of residues from a watershed into small feeder tributaries or stormwater feeder pipes which then open int retention ponds or farmponds within the drainage basin. Effects to estuarine fish have generally involved shallow lagoons or tidal waters at low tide following mosquito control uses.

Risk for Amphibians

Routes of exposure for amphibians are expected to be through direct contribution of residues to aquati habitats where adults or their offspring reside or through dermal adsorption from spraydrift to terrestri areas where they might reside. Based on risk criteria for fish(½ the LC50 = Level of Concern) risk to tadpoles of sensitive frog species will occur with aquatic EEC's of 100 ppb. This could occur from direct drift of less than 0.5 lbs ai/acre, or, using a worst case GENEEC scenario, runoff and/or drift from an approximate 2.0 lb ai/acre application of malathion. EFED has limited information on possible effects to amphibians from dermal adsorption of residues. In actual reports of adverse effects to aquatic organisms mortality of adult amphibians (usually frogs) has been reported as well as presence c malathion residues in tissues following non-lethal exposures. These adverse effects generally involve malathion contamination of shallow wetland areas where flush rates are slow. Exposure of aquatic eggs or larvae of amphibians to malathion residues in surrounding water is also a potential route of exposure which could lead to adverse effects to developmental stages of amphibians.

Risk for Reptiles

Acute risk for adult reptiles is not expected from most malathion uses. Oral ingestion or dermal adsorption of residue laden water might be the most likely route of exposure for aquatic reptiles. In several of the reported fish kills for malathion, adverse effects to aquatic turtles was also observed. However, confirmation that the turtles were killed by malathion alone is not provided. Effects to developing eggs of reptiles from direct exposure is also of concern when malathion uses provide potential exposure to shoreline nesting sites.

Risk to Nontarget Plants

Malathion is not expected to pose a serious hazard to terrestrial plants or aquatic algae as the mode of action (effects to nervous system) would not apply to plants. Malathion is expected to be systemically absorbed into plant tissues based on field study analyses of plant tissues after malathion applications. The Agency has received no reports of adverse reactions of crops or plants to malathion itself though label advisories for forest use do caution against application to certain species of trees.

Risk to Non-Target Insects

Malathion has been shown to be lethal to many species of beneficial insects at rates routinely employe in agricultural settings. The routes of exposure may be direct contact, contact with foliar residues, and contact with residue coated pollen transported back to nests or hives. Aquatic larvae of terrestrial species may also be acutely effected for limited time periods through residue drift or runoff to stream or other aquatic habitats. In Giles' review of effects of malathion application to a hardwood forest (see previous summary) the author made a pertinent summary of the predictability of what may occur to insect populations. "Effects will range from none to near complete extermination of species on the are Insecticidal effects on certain populations may be obscured by drastic predator-prey-host-parasite shifts caused by the insecticide. The resistance of natural populations and the immediate recharge and stabilization of populations will obscure effects of insecticides. Egg and larval stages, unmeasured by sampling techniques may be affected, the results of which may be postponed or may remain unrecognized. Aquatic populations may be affected with subsequent effects on insect eggs, larvae and later, adults. The result is a multidimensional web of action and interaction between and within species and their natural environment and an unnatural environmental hazard, malathion insecticide." This same summary may also be applicable to malathion effects when used near or over other non-agricultural areas containing beneficial insect populations, such as salt marshes, riverbanks, meadows and natural grasslands.

Factors Influencing Malathion Exposure Levels

The effect of lower application/use rates on aquatic malathion concentrations was examined using PRZM-EXAMS modeling. All input variables were those used in Mississippi cotton modeling except that the application rate was varied from 0.4 to 1.2 lbs / A (Table 41).

Table 41. Predicted aquatic malathion concentrations with varying application rates. Values represent the highest average concentrations expected in a ten year period. For example the highest 96-hour average concentration expected during a ten year period at 0.4 lbs/A is 23.551 ppb.

App rate (lbs/A)	YEAR	PEAK	96 HOUR	21 DAY	60 DAY	90 DAY	YEARLY
0.4	1/10	41.62	23.55	6.94	4.16	3.00	.93
0.6	1/10	61.96	35.06	10.34	6.20	4.47	1.39
0.8	1/10	83.22	47.09	13.89	8.33	6.01	1.87
1.0	1/10	103.44	58.62	17.30	10.37	7.48	2.33
1.2	1/10	123.75	70.12	20.68	12.40	8.95	2.78

PRZM-EXAMS modeling results suggest that peak and chronic aquatic concentrations directly correlate with application rate.

It is not possible to directly assess the effect of decreased application rate from monitoring data because application rates were constant at the locations of use. However, monitoring results suggest that the most important source of aquatic contamination is through spray drift.
Table 10 shows malathion levels in undiluted runoff water. In 38 runoff measurements collected at distances of 0-135 feet from the treated field only once did the malathion concentration exceed 100 ppb and in most cases the concentration was less than 10 ppb. It is expected that runoff from fields would be diluted to varying degrees depending mostly on the size of the receiving water with larger bodies resulting in dilutions several orders of magnitude.

Because monitoring studies were conducted in a limited number of locations, all with soil types suitab for cotton, it is possible that soil half lives may be longer in other areas where malathion is used. Malathion persistence varies greatly in soil, ranging from less than one day to greater than five days. Soils with longer malathion persistence would be expected to have higher runoff potential.

Lower numbers of permitted seasonal uses at use rates in excess of 1.25 lbs ai/acre reduce length of exposure of sensitive bird species and possibly other equally sensitive terrestrial wildlife species to multiple peaks of malathion levels which are in exceedance of chronic concern levels. In addition the amount of residues potentially available for runoff would be reduced.

Multiple Application Intervals

Terrestrial modeling results indicate that malathion degrades rapidly enough to avoid terrestrial residue buildup on vegetation in typical scenarios if intervals are 7 days or more. Slight increases in residues occur with 3 or 5 day intervals. Seven day or greater intervals appear to provide little residue increase over levels predicted for a single application.

Protective Buffer Zones

Monitoring studies have shown that buffer zones will reduce off-target spraydrift to aquatic habitats. This is particularly important when potentially exposed aquatic habitats are shallow or slowly flushed such as marshes.

Timing of Applications

In cases where beneficial pollinators are potentially exposed to toxic pesticides applications can be reduced during blooming periods or limited to dusk periods when pollinators are less active. Dawn applications may lead to more immediate exposure without the hours of potential degradation time offered by evening applications. However, it should be noted that this measure will not adequately protect beneficial insects from exposure to foliar residues. In the case of adulticide uses for control saltmarsh mosquitoes, applications can be made during incoming tides to increase flush rate and provid additional dilution of residues that might drift to these habitats.

Storage conditions

Malathion degradation to products of higher toxicity under improper storage conditions is well documented, however effects due to impurities and degradates during normal use are not (with the exception of the mass poisoning of 2,800 spray men in Pakistan in 1976 resulting in 5 deaths, Aldridge *et al* 1979). Practices of major malathion using programs greatly reduce the amount of impurities and degradates released at application. Closely monitored programs using malathion (*ie* boll weevil and medfly eradication programs) are likely to have fresh stocks of pesticide and for the Boll Weevil Eradication Program the registrant removes remaining stocks at the end of pesticide spraying season. These factors reduce the probability of adverse effects due to degradates however it does not necessarily reflect normal operating conditions and procedures for smaller applicators which are not as closely monitored. Malathion stored for long periods of time clearly increases ecological and human health risks.

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